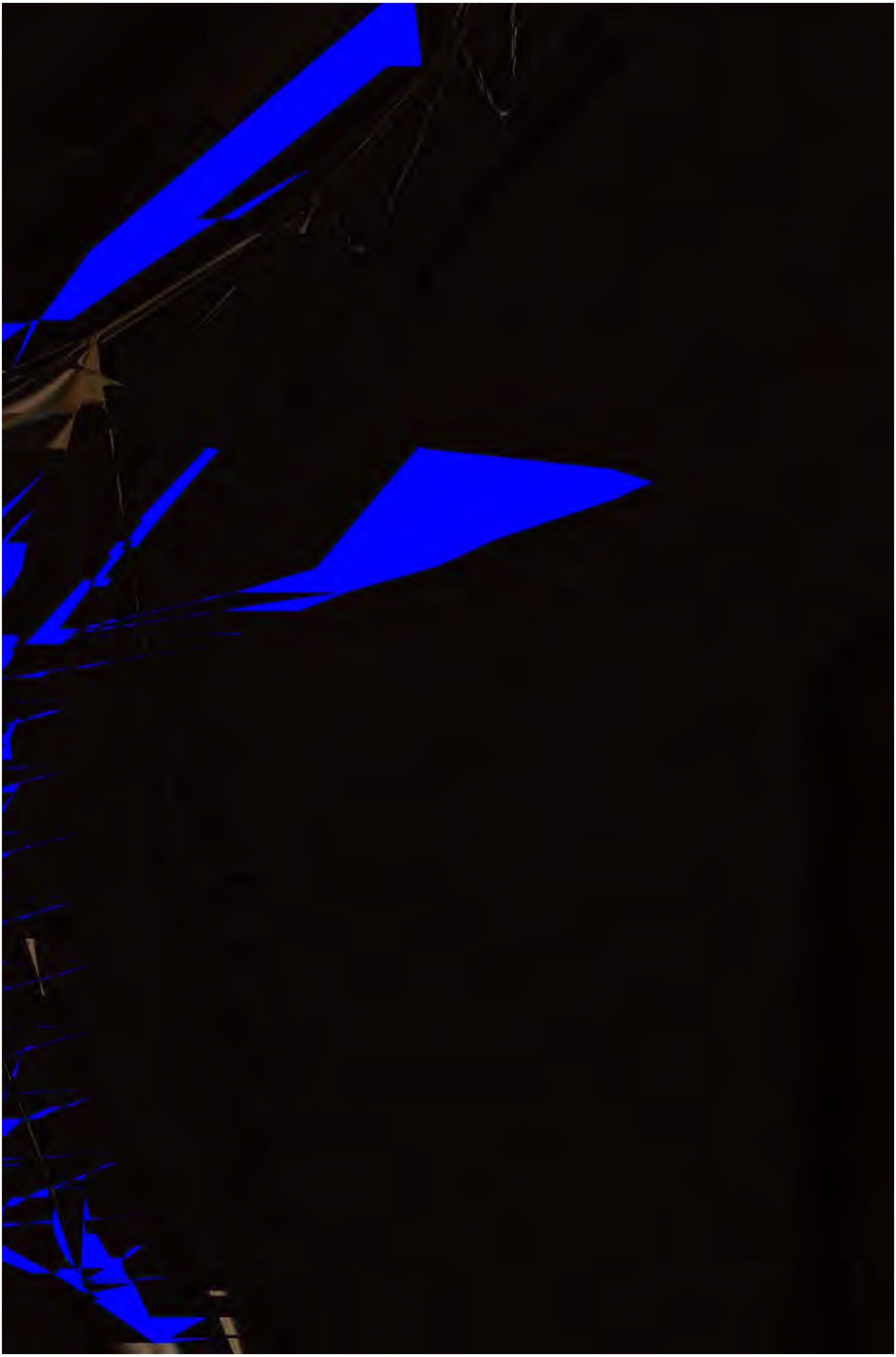

MODERN PHYSICS:

STUDIES HISTORICAL AND PHILOSOPHICAL.

BY

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Translated from the French

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EDINBURGH:
T. & T. CLARK, 38 GEORGE STREET.
1884.

PRINTED BY LORIMER AND GILLIES,
FOR
T. & T. CLARK, EDINBURGH.

LONDON, ... HAMILTON, ADAMS AND CO.
DUBLIN, ... GEORGE HERBERT.
NEW YORK, . . . SCRIBNER AND WELFORD.

PREFACE.

THE establishment of a system of physics, resting upon solid bases, is the greatest scientific fact of modern times. The prediction of Lord Chancellor Bacon has been triumphantly fulfilled; the power of man over nature has increased in proportion to his knowledge. Railways, the electric telegraph, and many other marvels of industry, forbid all dispute as to the value and practical utility of the labours of our natural philosophers; but the original sources of contemporary physics, and the philosophical consequences which may legitimately be deduced from the discoveries due to physical science, are very often unknown. The reader will find in the following pages information upon these two points, and the correction of some false notions pretty widely extended. He will find also, if I am not mistaken, the justification of views set forth on the subject of the scientific method in my Essay upon the "Logic of Hypothesis."[1]

[1] "La Logique de l'Hypothèse," 1 vol. in 8vo, de la Bibliothèque de Philosophie Contemporaine.

The work of which this volume is the result, has been accomplished with the aid of the kind association and counsel of Auguste De la Rive. In acknowledging the services rendered to me by that illustrious savant, I fulfil a duty of justice and gratitude, without wishing to excuse myself, in any measure, from the errors into which I may have fallen.

I must also, making the same reserve as for Auguste De la Rive, express my grateful acknowledgments to MM. Edouard Sarasin and Charles Soret, who have been so good as to afford me the help of their intelligent co-operation.

ERNEST NAVILLE.

GENEVA, 12*th November*, 1882.

NOTE BY THE TRANSLATOR.

"PHYSICS and Metaphysics" might be the title of this volume, which is, in a manner, the joint production of two men, eminent, the one in one, the other in the other, of these two sciences.

M. De la Rive, as we learn from the preface, and from the note on page 1, was associated with the Author in the preparation of his work, at least in the way of frequent and intimate discussions upon the subject of it; and M. De la Rive, one of the eight foreign Associates of the French Institute, was well known as one of the greatest physicists of his time; while the Author himself, the biographer of Maine de Biran, and the Editor and Expositor of his works, and a correspondent of the Institute, needs no introduction to the intellectual magnates of this or any other country.

It has appeared to the Translator that this work thus meets in a way of rare advantage the subtile speculations of some prominent writers of the day. In

this belief he has undertaken the labour of presenting it to the English public. This he does, not in the hope of convincing the unbeliever, for his errors are more of the heart than of the head; but for the confirmation of the faith of any who may have been perplexed by his arguments, and that he may help the honest doubter to "beat his music out."[1]

M. Naville appears to accept the theory of evolution, at least as an hypothesis, the truth of which, he says in a former work,[2] "must be left to the future, enlightened by experience and by the employment of a sage induction." But he says further, that "though we grant everything to the extreme pretensions of naturalists," yet that the question of man's spiritual nature must not be "put out of sight beneath details of physiology and researches of natural history, which can neither settle, nor so much as touch, the problem."

In this work the Author's object keeps him wholly clear of the question of Revelation and religious creeds; but if any wish to know his position relatively to these subjects, they may be referred to his four courses of popular lectures, delivered at various times at Geneva.[3]

[1] "In Memoriam," xcvi.

[2] "Modern Atheism; or, The Heavenly Father," translated by Henry Downton, M.A. Nisbets, 1882.

[3] (1) "Eternal Life"; (2) "Modern Atheism"; (3) "The Problem of Evil"; and (4) "The Christ." Translations of the two last have been published by Messrs. T. & T. Clark.

The following is an extract from the first of these:—

"If science proved, with certainty, that the intervention of God is a chimera, we should only have to veil our face and weep the loss of our hopes; and it is said that this is so. It is pretended that the criticism of our time has consigned Christian doctrines to the number of superstitious beliefs. This assertion will become the object of our examination. But they go farther, and not only avail themselves of the results of science, but affirm, in a general way, that faith in the supernatural is incompatible with intellectual culture; that the intervention of God in the world is a gross conception, mechanical, unworthy of a cultivated man of the nineteenth century, and which does not even merit the honour of discussion. These voices come from all quarters. Germany sends them to us: Paris sends them back in its turn, and I fear that the echo of our mountains only too clearly responds to them. I hear this talk, it distresses me, . . . and it does not disturb me!—The Gospel is folly in the eyes of a certain kind of wisdom,—no doubt!—St. Paul says that it is so, and Jesus Christ gives us to understand the same. But there are so many things which are folly for a certain sort of wisdom. Duty, in its austerity, appears a folly to the man of pleasure: devotion to others' good is folly for the prudent calculations of human wisdom. Then, in that sort of humiliation in which

our faith as Christians places us amongst the learned, we do not lack consolations and sufficiently rich recompenses for our self-esteem. The savants of the School of Alexandria who rejected the preaching of the Cross were full of erudition and intelligence; but he was no dull, witless pretender—that Bishop of Hippo, who bore the name of Augustine. In these more modern days, I think of Leibnitz, who was not a petty philosopher nor an every-day geometrician, and who never spoke of the verities of the faith but to respect or defend them. I remember Pascal, who, without vain ambition, might have aspired to become the first natural philosopher of his day, and one of the most illustrious mathematicians of the universe, and who one day broke off his calculations, and left his barometers, to give himself without reserve to the cause of Jesus Christ. I bethink me of Newton, a tolerable astronomer, who never heard mentioned the God of the Gospel without some token of respect, and who dares to conclude a book of physics[1] by quoting the summary of the law—to love God with all the heart, and one's neighbour as one's self. I hear say again, that, at an epoch nearer to ourselves, men who have reached the loftiest heights of science have been willing to descend that they may believe, adore, and pray with the humble. In the society and conversation of these

[1] "Treatise on Optics."

illustrious dead, you might choose your side, if some fine spirit of the present day, or some modern savant, marking you on the forehead with the mark of small minds should, on his own private authority, shut the gate of science against you, and pronounce you unworthy of his learned company.

"This is not argument, nor even serious talk; only it seemed desirable to show that to the prejudices of the modern mind we have the means of opposing others. But God keep us from introducing, in the search after truth, the paltry considerations of *amour-propre!* And woe to us if, when the question is that of our most serious interests, we blindly abandon ourselves to that capricious and fickle power which they call the spirit of the times, without reflecting that, by this very designation, they testify that, born of yesterday, this ephemeral power may have ceased to exist to-morrow."

In the quotations, scattered throughout the volume, from Mr. Herbert Spencer, Professor Tyndall, and other English authors, the translator has contented himself with re-translating the French versions, as referred to by the Author.

[1] "La Vie Eternelle," Sept Discours par Ernest Neville. 1re édition. Paris: Joël Cherbuliez, 1861, pp. 143-145.

HOPTON RECTORY, THETFORD,
6th November, 1883.

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FIRST ESSAY.

The Characters of Modern Physics.[1]

THE word "Physics" has, in the course of time, received various significations. The ancient Greeks sometimes designated by this term all the science of realities, as distinguished from the study of abstract ideas. They used at that time to class all the researches of the human mind taken together under three heads: Logic, or the science of the laws of thought; morals, or the science of the rules of action; and physics, or the science of entities. This last science, then, had as its object not only matter but living beings, minds, and the First Cause of the universe. It included our natural history, our psychology, and

[1] A first edition of this first essay was published in the *Bibliothèque universelle* (July and August, 1872). M. de la Rive, who had been so good as to examine the most important parts of the manuscript, expressed his satisfaction with it. His death, which took place on the 27th November, 1873, deprived me of the advantage of his judgment as to the way in which the subsequent essays, which were published first of all in the *Revue philosophique*, *La Revue scientifique*, and *La Bibliothèque universelle*, set forth ideas which often formed the subject of our conversations.

our theology. In our day the word "physics" has indicated a special study—"that of the general properties of bodies, and of the phenomena which do not entail permanent changes in their inner composition," the study of these changes being left to chemistry. This is the definition given by M. Lamé in his lectures to the *École Polytechnique.* In the present language of science, the word "physics" tends to take a more extended meaning. M. Robert Mayer has used it to designate "the entire science of inert matter.[1]" The word has the same sense in the *sciences physiques* of the classification of Ampère, in the title of the *Archives des sciences physiques et naturelles,* joined to the *Bibliothèque universelle,* and in the title of the work devoted by M. Emile Saigey to the theory of the unity of natural phenomena.[2] Thus conceived, physics begin at the appearance of matter, which separates this science from the purely abstract sciences—logic and the mathematics. They stop at the appearance of life, which separates the science of physics from botany and zoology, two sciences now united, by a happy neologism, under the title of *biology.* It contains, therefore, mechanics, including celestial mechanics, chemistry, mineralogy, physics in the narrow sense of the term, meteorology, and the part of geology which does not involve the consideration of living beings. It is an auxiliary science for biology, just as mathematics are

[1] Discours au Congrès des naturalistes Allemands réuni a Insbruck, en 1869.

[2] *La Physique moderne, essai sur l'unité des phénomènes naturels.* Paris, Germer Baillière, 1867.

an auxiliary science with respect to it. All the sciences which have just been enumerated, form a natural group, because they have a common object—inorganic matter; and because the unity of the laws which govern the phenomena with which they are concerned is always more manifest in proportion as the study makes progress. The word "physics" has in this work the general sense which has just been pointed out.

The expression "modern physics" is not a barren designation, indicating a state of the science new to-day and which will be old to-morrow relatively to another which will become old in its turn with regard to that which will succeed to it. These terms have a positive force, because they mark a determination of the nature of the material phenomena which is clearly enough distinguished from notions previously admitted to mark an epoch in the history of the science. Under the name of ancient physics, I bring together ideas which belong to different epochs, but which have this character in common, that they deny or ignore the fundamental conception which constitutes modern physics. A date may indeed be assigned to the birth of this conception; but the date of its appearance is not that of its full development and its undisputed triumph. A new doctrine has always to sustain a struggle against ancient doctrines, which for a certain time maintain their ground. As Ritter, the historian of philosophy, has remarked,[1] the periods which may be established in the history of ideas never have a strictly chronological character; they resemble less a mechanical division

[1] "Histoire de la Philosophie." Coup d'œil général et division.

than the chemical decomposition of a composite body.

The distinctive characters of modern physics may be ranged under three heads: Scientific characters, Logical character, Æsthetic character.

Scientific Characters.

The scientific characters are those which relate to the manner of conceiving the proper nature of the phenomena which are the object of the science. There are five of these which for their importance are worthy of being specially pointed out.

1. *Mechanical Nature of the Phenomena.*

The physical phenomena considered in themselves, and without reference to their connection with beings capable of feeling and perceiving, are reduced to motions. Sound, considered apart from the perceptions of the faculty of hearing; light and heat, separated from the sensations to which they give rise; electricity, magnetism, separated from the various effects which they produce upon sensible beings—are nothing but motions. Physical motions, meeting the organs of living beings, determine physiological motions. These motions are transmitted by the nerves to the cerebral centre. One may say that the physiological motion is only the physical motion transformed by the organs of the senses in pretty nearly the same way as the vibrations of the air in an organ are variously modified by the form and size of the pipes into which they penetrate. To the physiological motion of the cerebral centre correspond the

phenomena of sensation and perception, psychical facts harmonised with the motion of matter, but of a different order, and which become the starting-point of a whole world of thoughts and feelings. We will make this clearer by a few examples.

A lover of music is listening to a sonata of Mozart; what is it that is going on? The mechanical motion of the instruments determines the undulations in the atmospheric air. These undulations strike the external organs of hearing. The motion, modified by the ear, is transmitted along the nerves, and to this motion, arrived at the cerebral centre, responds the perception of sound, with which are associated divers impressions, emotions of the soul and of the thoughts. Take away the mind capable of hearing, and there will no longer be anything heard; there will remain only the vibrations of the air and those of the organs. An astronomer is looking at a star by means of a telescope; what is taking place? The star has a motion which produces undulations in a subtile fluid everywhere diffused, which natural philosophers take account of under the name of *ether*. These undulations reach the glass of the telescope, which modifies them. So modified, they are transmitted to the eye, which modifies them in its turn; and they arrive at the retina, where they produce a physiological motion. This physiological motion extends itself along the optic nerve, and reaches the brain. Then is produced, by virtue of the harmony which links together two orders of phenomena, the sensation of light and the perception of the luminous body. The astronomer feels; he sees; perhaps he admires; he reflects. Take

away the mind capable of seeing and feeling; what remains? The undulations of the ether, the several motions produced in the glass of the telescope, in the organs of the eye, and in the nervous system.

The words light, heat, sound, have two distinct meanings, and there is danger lest this double sense of the same words should produce confusions of ideas. These terms imply at one time physical phenomena which are merely such, the objective fact, at another time sensation and perception, or the subjective facts. These two orders of facts are connected by a relation which is one of the primitive elements of the universe, of which we do not possess the explanation, and of which it is even impossible for us to seek the explanation. Instead of establishing this relation, ancient physics used to create imaginary entities under the names of *substantial forms, occult causes, virtues of matter*. Sound, light, heat, cold, dryness, moisture, were considered as causes at which the mind stopped, supposing that it had explained the phenomena, when it had only named them.

To affirm that there exists nothing in bodies which resembles our feelings and our ideas; that the terms light, heat, &c., as soon as they are made to include a psychical element, are the expression of relations between two classes of phenomena distinct, though intimately united; to affirm that every physical phenomenon is in itself nothing but motion—such is the first character of modern physics. It is suitably expressed in these terms: The mechanical nature of the phenomena.

Bacon says, in the fourth aphorism of his *Novum Organum:* "To bring together natural bodies, or to separate them one from another, to this it is that all the power of man is reduced; all the rest nature operates in retirement and out of our view." We affirm at this day that in the whole material universe there is nothing else than motion, and that what Bacon calls "all the rest," is only a relation between the physical phenomena and the sensibility of living beings.

This theory takes for granted the existence of ether; that is to say, of a fluid subtile, without weight, elastic, penetrating all bodies, filling all the spaces which separate them; a fluid in which take place the motions which constitute light and heat. The existence of ether is not one of the immediate data of experience. The air can neither be seen nor touched; but it becomes the object of a direct perception in the action of the wind, and it may be weighed in a balance. Ether cannot be tested in this way. Its existence is an hypothesis; but this hypothesis is necessary for the explanation of the phenomena, and is warranted by the very success of the explanations which it supplies.

In order to understand well the reduction to unity of all physical phenomena, we must distinguish three kinds of motions:—(1) Those of bodies forming a mass more or less coherent (solid, liquid, or gaseous) which is transported from one point of space to another; (2) Those which are produced in the interior of bodies, which continue to occupy relatively the same portion of

space, but of which the molecules or atoms move; (3) Those of the supposed fluid which fills the intervals between the different bodies, and the molecules or atoms of each body. One may give the name of *mechanical* motions to those of the first kind, calling those of the second *molecular* or *atomic* motions, and those of the third kind *etheric*[1] motions. The employment of the first of these terms is not without its inconvenience, since all motion is essentially mechanical; but I have not succeeded in finding one more suitable.

2. *Unity of Matter.*

Motion does not manifest itself, and cannot be conceived of otherwise than as a mode of the substance of the bodies which are called matter. The affirmation of the unity of matter forms the second characteristic of modern physics. The meaning of this affirmation must be accurately defined.

Chemical analysis reduces the indefinite variety of natural bodies to a determinate number of elements called simple bodies. These bodies are found always the same in the apparatus of laboratories, and they differ one from another in relation to their weight and their various properties. The progress of science for the last fifty years has increased the number of these refractory substances by experiments of decomposition. Now, relying upon inductions sufficiently supported, chemists are conceiving the hope that they shall succeed in decomposing a part at least of bodies hitherto

[1] Éthériques.

regarded as simple. Certain theorists are coming to think that bodies having weight are composed of molecules which are but divers aggregates of similar atoms.[1] Some go further still, and suspect that ponderable bodies are formed by the aggregation of atoms of ether. According to this hypothesis, the elements of matter would be identical. What would be the origin of the diversity of natural bodies? This origin, from the experimental point of view, could be only the motions which would have brought together the elementary parts, to form of them the various masses.

The absolute uniformity of the atoms, and the variety of their aggregates resulting from motions which would have variously united them—this is, not a theory experimentally demonstrated, but a bold and grand conjecture. It is not in this sense that must be understood, at least in the present state of science, the thesis of the unity of matter. This affirmation, as it appears to be justified by the progress of physics, means that there do not exist divers forms of matter endued with specific properties unknown and undeterminable. All explanations of phenomena are to be sought exclusively in the form of bodies, and in their motions. Weight, cohesion, affinity will be determined as motions at one time in act, at another time simply as possible. The atoms may be supposed to be different, but only, from the geometrical point of view, in respect to the form; from the dynamical point of view, in respect to the tendency

[1] See, for instance, in the "Logique de l'Hypothèse," page 160, the opinion expressed by M. Marignac.

to motion. To affirm in this sense the unity of matter is to say that the nature of the phenomena is mechanical, so that the second characteristic of modern physics is but the assertion of an idea contained in the first. Ancient physics were based upon conceptions of another nature.

It was supposed formerly that bodies were divided into four classes—solids, liquids, gases, and fiery elements. This was the theory of the four elements—earth, water, air, and fire; and this theory prevailed till a period not far removed from ourselves. Solidity, liquidity, the condition of gas, and of fire, were considered as qualities of the different kinds of matter. Science did not seek to explain these qualities, which it considered as primitive, and which it consequently took as starting-points for its explanations. Later on, the causes of different physical phenomena were considered as distinct agents. Light, heat, electricity, the magnetic fluid, were reckoned as different forms of matter without weight, endued with particular properties, and indeterminable otherwise than by their effects. The observation of each new fact risked then to introduce into science the idea of a new fluid. Galvani, having chanced to suspend to a bar of iron a frog attached to a hook of copper, observed an unexpected movement in the limbs of the animal; so galvanism figured for a while in science as a new agent. In modern physics, it is considered that solid, liquid, and gaseous conditions may belong to all bodies without exception. The liquefaction of oxygen lately obtained by MM. Raoul Pictet and Cailletet has confirmed this opinion.

The following example will enable the reader to estimate the difference between the ancient and modern physics, in the explanation of a fact of detail. A mass of iron, laid upon an anvil, and receiving the blows of a hammer, becomes hot; here is a fact. How to account for this development of heat? According to the ancient system, the caloric was a subtile body, contained in the mass of iron, and it came out of it, under the shock of the hammer, just as water contained in a sponge comes out of it when the sponge is squeezed. According to modern physics, the fact is explained by the idea of the transformation of the motion of the hammer, as we are about to hear in the exposition of the following characteristic.

3. *Transformation of Motions.*

The third characteristic of modern physics is the principle designated by several savants under the title of *Correlation of Forces*, or *Transformation of Forces*, and which I prefer, with M. de la Rive, to call the principle of the *Transformation of Motions.*[1] These expressions are substantially equivalent. In fact, under the name of force is signified a cause of motion; but a cause of motion, a force, can never, as Laplace remarks,[2] be determined except by its effects, which are motions, and by the law of its action, which is only the law of the motion. A force cannot therefore enter into the calculation, and serve for a scientific explanation, otherwise than as being determined by the motion which

[1] *Archives des Sciences Physiques et Naturelles*, Dec. 1871.

[2] "Exposition du Système du Monde," livre iii. chap. i.

it can produce. It is measured by the mass put in motion, joined with the degree of acceleration, and by the acceleration, account being taken of the mass. The considerations relative to the cause of motion, that cause being regarded by itself, and independently of its effects, lie outside of the domain of physics studied as a particular science. Observation only reveals to us actual motions, or a state of bodies from which will result such and such motion under given circumstances. The experimental determination of a force is therefore always an actual or virtual motion; and this is why the terms correlation of forces and transformation of motion are two different expressions of the same thought. Let us observe, that in speaking of the transformation of motion we merely point out a condition of matter which is passing from one body to another. One motion produces other motions: this is the meaning of the principle. Mechanical motion, molecular motion, etheric motion, are mutually produced; and etheric motion, for instance, produces in us the sensation of light. One cannot say that the motion is transformed into light or heat, if in the terms light and heat is comprised the element of sensation. In that case there is the harmonic correspondence of a material fact and a psychical fact, and not a simple mechanical transformation.

According to the modern theory, the heating of a mass of iron beaten on an anvil is explained as follows: The hammer executes a mechanical movement. The effect of this movement is in part to modify the external shape of the iron, and to shake the anvil; but another part is represented by a movement of mole-

cules, whether of the hammer or of the beaten iron; and the molecular movements produce an etheric movement, which is the objective part of what we call heat—that is to say, the cause of the sensation. If you will say that the motion is transformed into heat, it must not therefore be forgotten that this is an abridged expression which indicates the transformation of one motion into another to which the sensation corresponds. Treatises on physics teach that, in order to judge of the state of the temperature, we must not trust our impressions, but observe the dilatation or condensation of a body. The meaning of the terms being well explained, we may without inconvenience make use of the formula that motion is transformed into heat. Inversely, a disengagement of heat, whatever be its origin, may be transformed into mechanical motion. This is, in fact, going on every day in the machinery of our railways and steam vessels.

The observation of the relations obtaining between mechanical motion and heat became the starting-point of a general theory which establishes a mutual connection of all the physical forces. In 1843, an English natural philosopher, Mr. Grove, displayed an apparatus at work, by means of which, with a ray of light as initial force, he obtained a chemical action of electricity, of magnetism, of heat, and of motion. The mutual relation of all these phenomena may be equally made evident by taking a mechanical motion as the initial force. Let us consider, for instance, a block of marble, which workmen, employed in erecting a building, have just placed on the top of a wall. Suppose we

are supplied with all suitable apparatus, mechanical and physical, and it will be possible, by making this block of marble descend, to obtain, through the phenomenon of friction, heat, light, electricity; we shall be able to decompose a body into its elements, and to recompose it.

The observation of the phenomena therefore establishes with certainty that a mechanical motion not only produces other mechanical motions—a fact which has never been unknown—but produces also molecular and etheric motions, these last taking in science the place occupied erewhile by divers imponderable fluids. How may the cause of these transformations be conceived of? It will be sought in the form of the molecules, and in the mode of the vibrations of the ether; it will be found some day, if it shall become possible to establish the mechanics of atoms and of ether on bases as firm as those of the mechanics of solid masses. This is the end set before physics under the direction of contemporary science—an end which shows itself as a far-off hope upon the distant horizon of thought.

4. *Conservation of Energy.*

If we stop at appearances, we may suppose that, in certain natural phenomena, there are elements of matter which are annihilated. It seems, for instance, that a body which burns away is destroyed. The labours of chemists have shown that this is not the case. If all the gases produced by the combustion of a body are carefully collected and weighed, and their weight added to that of the solid residuum which may remain,

and if the weight of the oxygen absorbed is taken away, a sum is found precisely equal to the original weight of the body. We affirm, therefore, by an induction based upon numerous observations, that, in the part of the universe which our experience can reach, there is neither creation nor annihilation of matter. A like theory applied to the principle of motion is the fourth of the characters which we are passing in review.

Ancient physics admitted that, in the phenomena of collision and of friction, there was force lost. There was no idea of looking for the equivalent of the motion which was seen to disappear in the production of phenomena of heat, light, or electricity. Modern physics affirm that the sum of actual or virtual motions remains the same. They affirm that a mechanical motion which disappears may be transformed into a molecular motion, and, by the medium of a molecular motion, into an etheric motion. That this affirmation may be well understood, two remarks are necessary.

1. In mechanics, by quantity of motion is understood the product of the mass of a body into its velocity, a product of which the algebraical expression is $m\,v$. Now, experience shows that, to increase the velocity of a body, there must be an expenditure of force proportional, not to that velocity itself, but to its square. So, to double the velocity of a cannon-ball, the tension of the gases produced by the combustion of the powder must be quadrupled. The product of the mass by the square of the velocity is called *live force*,[1] and this

[1] "Le produit $m\,v^2$ de la masse d'un point matériel par le carré de sa

product is expressed by the formula $m\,v^2$. It is seen from the preceding explanation, that the conservation of the same quantity of motion, and the conservation of the same quantity of live force, are two distinct things. If it is desired to find in a calculation the amount of the force, a body moving ten times more quickly must not enter into the account for ten, but for a hundred. Experience proves that in the consideration of actual motions it is not the quantity of the motion $m\,v$ which remains constant, but the quantity of the force $m\,v^2$.

2. Forces, being considered as causes of motion, are not always manifested by a realisation of live forces. Weight, for example, is manifested in the fall of a free body; but it does not less exist, without manifesting itself by actual motion, in a body which does not move, but which exerts a pressure upon the ground which supports it, or a tension upon a cord which sustains it. A spring when stretched constitutes in the same way a force which is not realised in appreciable motion. It is, therefore, a vain attempt of certain contemporary savants, who would get rid of the idea of force, which they regard as a useless abstraction, so as to keep only the idea of actual motion. The interpretation of the phenomena demands that we admit, along with actual motions, virtual motions; that is to say, causes of motion in a latent, or simply potential condition.

By means of these two explanations we may understand in its true sense the principle which forms the

vitesse, se nomme *la force vive* de ce point."—Delaunay, "Traité de Mécanique Rationnelle."

fourth of the characters of modern physics. That which remains in equal quantity in all the transformations of motion, is the motive power whether in exercise or not. By what terms must we describe it? At first the term *constancy of force* was adopted; but the word "force" has in mechanics a precise meaning; it expresses the mass multiplied by the acceleration. For this reason it is now thought better to use the term *conservation of energy.* These two expressions have, however, exactly the same meaning. Energy is the cause of motions, actual or virtual. It is at one time in the state of realisation in the active forces,[1] at another time in the potential state. The principle consists, then, in the affirmation that in all observed phenomena "the sum of the active forces and of the potential energies is constant."[2]

It is the comparative study of mechanical motion and of heat which has chiefly contributed to establish this principle. The *kilogrammètre* has been taken as the unit of mechanical motion; that is to say, the labour necessary to raise a kilogram to the height of a *mètre.* As the unit of heat has been taken the *calorie;* that is to say, the heat necessary to raise by one degree centigrade the temperature of a kilogram of water. Numerous experiments have proved that one *calorie* is equivalent to about 424 *kilogrammètres;* that is to say, that the heat necessary to raise by one degree the

[1] *Dans les forces vives.*

[2] Helmholtz, "Mémoire sur la Conservation de la Force," page 77. See also "La Conservation de l'Énergie," by Balfour Stewart, a volume of the "Bibliothèque Scientifique Internationale."

temperature of a kilogram of water, would suffice, if in practice it could be utilised entirely, to raise one kilogram to the height of 424 *mètres*. This result is generalised by admitting that equivalence exists in the transformation of all the classes of motions which constitute light, heat, electricity, and magnetism. All motions, when it shall be possible to bring them to determined units, will be capable of being valued by the common measure of the *kilogrammètre*, and, when they shall have been brought to a common measure, it will be in our power to prove their equivalence: such is the theory.

Let us take, again, the example we just before employed, that of a block of marble raised to the top of a wall. The first step in the business was the work of the labourers, who exerted the force necessary to overcome the weight of the block. Their labour is measured by means of that weight itself, and the vertical space passed through. We have supposed the block to be descending, and its mechanical motion becoming the origin of a whole series of phenomena. When it shall be possible to take an exact account of these phenomena, which objectively are only divers motions, and to obtain the sum of them, that sum will be found to be precisely equal to the labour of the workmen who raised the block. It will be found again, as one finds again, after combustion, the sum of the weight of a body which has been consumed by fire. This conception has been applied to the stone placed at the summit of the pyramid of Chephrenes, with the remark that it has retained all the labour expended on it, four thousand

years ago, by the workmen of Pharaoh who set it in its place, and that it is ready at any time to give it back, in such a form as may be required, without retaining any part of it, or adding anything to it.[1] Under what form does the power of labour exist in the stone? Under the form of weight, a constant force, of which the elevation of the stone only modifies the point of application. But how does the virtual motion exist in the weight, when the heavy body is in the condition of rest? To generalise the question, How does virtual motion exist in a bent spring, in a combustible body which will produce heat, in the powder the explosion of which will hurl a projectile? Different expressions are made use of to express the fact: *potential energy* (this is the term most commonly used now), *latent force, effort.* They talk of *stored-up force,* and of *provision of force.* Of these various expressions, some, as those of energy and effort, have a psychological origin; others, as that of stored-up force,[2] would not be applied with accuracy except in a theory which would make of force what ancient physics made of caloric, a particular substance of which one could make provision. We are here in presence of a fact which must be taken note of, because the observation of it is indispensable to science—the existence, namely, of motion in the virtual state, or of energy in the potential state: except on this assumption, the theory of the

[1] The idea, I think, is Robert Mayer's. See in the *Journal des Savants*, of November, 1869, pages 663 and following, the work of M. J. Bertrand upon the revival of the Cartesian system of physics.

[2] *Force emmagasinée.*

conservation of energy cannot be established. Potential energy is an expression which has a mechanical meaning perfectly clear; it is the amount of the work which the forces which act upon a system are capable of producing. But is it desired to explain the mode of existence of the motive power considered in itself, and not in its possible effects? All attempts at objective representation fails. Will it be possible hereafter to reduce the potential energy of weight and that of a bent spring to an internal molecular motion? Theoretically, one cannot pronounce the thing impossible; but what it is of great importance to note is this: In the present state of our knowledge, we cannot affirm the constancy of the force manifested by actual motions; the explanation of physical phenomena cannot dispense with the consideration of force in the potential condition. The savants of the present day, therefore, who are wishing to get rid of the idea of force in order to preserve only the idea of motion are making an affirmation which experience does not justify.

5. *Mathematical Explanation of the Phenomena.*

The mathematical explanation of the phenomena is the fifth character of modern physics. If all the phenomena which are studied in this science are reduced to motions, the entire science must be regarded as that of mechanics, understood in the largest sense of the term. Now, the elements of which the science of mechanics disposes are: time, space, speed, or the relation of time to space; and finally, the form of bodies and their mass. We must settle, therefore, a unit of

measure for time, a unit of measure for space, and a unit of measure for the mass; and these units once settled, mathematics, being applied to them, will furnish the explanation of the facts. The science of physics, therefore, regarded in its highest abstraction, and as it may be supposed to be when it shall have attained the end of its efforts, would be reduced to an assemblage of algebraical formulæ expressing forms and motions. This fifth character is the immediate consequence of the first; that is to say, of the affirmation of the mechanical nature of the phenomena. It supposes, however, for its full realisation, the transformation of motions and the conservation of energy, so that, flowing from the first character, but supposing the rest, it offers the summary of the conception of the science.

All contemporary studies are converging towards this end. Chemistry is coming more and more to look upon weight as the essential quality of the bodies which it studies; and the employment of the balance is but the application of arithmetic to a particular kind of quantity. Sounds being considered as vibrations of the air, their succession which constitutes melody, their consonance which constitutes harmony, are always reduced to determinate numbers of vibrations, and to the relation of those numbers, so that the theory of music is a mathematical theory. The discovery of the equivalence of heat and of mechanical labour had for condition the establishment of a unit of heat, which is determined by a unit of weight and a unit of length. These units established, the rest of the theory consists in numerical calculations. The same is the case with the theory of

light. The length of the waves, and the number of undulations in a given space of time, furnish the explanation of the diversity of colours, that of the dispersion of light, and of all the other phenomena of optics. Tables are formed, containing on one side the name of the colours, and on the other a number of undulations which correspond to them; and it is this number alone, to the exclusion of all idea of specific and unexplained properties of the rays, which becomes the basis of the scientific explanations. We may conceive our knowledge to have reached, in this respect, to such a degree of precision, that we might be able to establish a mathematical theory of painting as of music; and to express by the abstract relation of numbers the objective conditions of the beauty of a canvas of Raphael as well as of a symphony of Beethoven.

There had been glimpses of this general result, to which contemporary science is tending, in the first days of the awakening of philosophic thought. When we speak of mathematical physics, we do but express, under another form, what Pythagoras, returned from Egypt and Chaldea, used to teach the Greeks when he told them that "everything is number." This antique formula, so astonishing at first sight, takes a clear meaning when one has understood the tendency of actual researches.

The mathematics express the laws of human thought, which are found to be the laws of observed phenomena. It is this harmony of thought and of facts which renders the universe intelligible to us. It is sometimes said that, in the present state of science, consideration is no

longer given in nature to anything save matter and motion; it must be added—and *to the laws of the communication of motion.* Geometry and arithmetic do not exist merely in our thoughts; they have an objective reality, in so far as they regulate the relations of the objects of our perceptions. I make this remark without now insisting upon it, as I shall have occasion again to recur to it.[1]

Having now enumerated the scientific characters of modern physics, let us endeavour to form an idea, at once general and precise, of the difference which separates the modern from the ancient system.

Comparison of Ancient and Modern Physics.

The various sciences, in seeking to trace things back to their origin, arrive always, and of necessity, at a point where thought is arrested, and which becomes the starting-point of all explanations. Pascal, in his reflections on the geometrical spirit, remarks that we can conceive ideally of a science which should employ no term which had not been defined, and no proposition which had not been demonstrated; but he observes immediately that this conception is chimerical, for that from term to term and from proposition to proposition, we should have to go back to infinity. The science of physics, in pushing its theories as far as possible, will always arrive at a state of things, or at a *how*, of which it will not look for the *why*. Whether this state of things, held for primitive, exists by itself, or whether it be the

[1] See the Fifth Essay.

manifestation of a creative power, is a question of philosophy which is outside the programme of physics. In the two cases, the point of stoppage is the same; and this is what the learned atheist misunderstood, who said one day, "If God existed, the thread of science would be cut for ever." The thread of science is no more cut by the idea of the Creator than by that of the nature of things; and do what we will, thought must stop at a point of departure which will give account of all the rest, and of which no account will be given, for the very reason that it is a point of departure. The question is to know where the point of stoppage occurs. It is on this subject that there are found in physics two opposite doctrines. Ancient physics, being most conformable to the immediate data of experience, stopped at each class of distinct phenomena, supposing, for their explanation, particular properties or special laws. Hence came points of stoppage in indefinite number; each new fact tended to introduce into science a new principle of explanation. To this conception is opposed that of modern physics, for which all explanations must be reduced to principles of mechanics, which causes that thought has points of departure of a precise nature and in limited number. Some fresh examples, added to those already given, will make clear the fundamental opposition of these two points of view.

It was admitted, at the beginning of this century, that the simple contact of two metals produces electricity. A stop was made at this fact, and it was formulated as a law furnishing the explanation of the phenomenon which it expressed. Some natural philosophers carried

their researches further. M. De la Rive, among others, was struck with the idea that there was so admitted an indefinite production of electrical action without concomitant phenomena, either physical or chemical; that is to say, in fact, perpetual motion. He laboured, therefore, from the year 1828, to enrich science with the discovery of the chemical sources of electricity, a discovery fully confirmed since then by the labours of Faraday and other savants. To explain the production of a physical action by the simple contact of two metals, by virtue of an unknown property; such was the ancient system of physics. To explain that action by the transformation of an anterior action; such is the new system. Here is another example: the union of two electricities produces light. To stop at this observation, formulated as a law, is to point out the phenomenon, not to explain it. In order to explain it, as it is now viewed scientifically, we must conceive of electricity as a mechanical action producing a development of light.[1] The mind no longer stops, since then, at the simple succession of two facts (the meeting of electricity—light), it goes back to the conception of motions transformed according to the laws, unknown still in their precise formulæ, of molecular mechanics.

A system of physics stopping at divers classes of phenomena as at facts primitive and irreducible, and another system which reduces all the objective part of the phenomena to motions expressed by mathematical formulæ—such are the two conceptions which charac-

[1] Lecture by M. De la Rive, delivered at the *Athenée*, Geneva, 2nd January, 1872.

terise, in their diversity, the ancient and the modern science. If in our physics we are on a good road, the science of matter is destined finally to succeed in furnishing its explanations by means of these three data: the form of bodies, motion, and the laws of the communication of motion. Is this hope well-founded, or should we, in indulging it, be the victims of an illusion similar to that of those navigators who cry, "Land! land!" when they have only seen banks of cloud upon the horizon? This is a question to be decided in the future.

What certainly is an illusion is the idea now-a-days entertained by some, that the science of physics can reduce its object to absolute unity, by considering nothing save motion only. The science of matter includes, and always will include, two distinct branches. The one contains the researches relative to the constitution of the various aggregates, and to the nature of atoms, or the first element of bodies, whatever the name one may choose to give it. The other contains the researches relative to the laws of the communication and the transformations of motion. And here are, in a way, the anatomy and physiology of the material universe. The researches of the first class answer to our chemistry; the researches of the second class constitute physics, in the narrow sense of that term. These two branches of the science are distinct, but united by intimate relations. In biological studies, physiology supposes the existence of the organs, and, on the other hand, it seeks to explain their formation. It is the same in the study of inorganic matter.

Cohesion unites the molecules of similar bodies; affinity unites in molecules atoms primitively diverse; but this union of the elements of matter into aggregates cannot take place except by motion. On the other hand, all manifestation and all transformation of motion supposes pre-existent bodies. There is therefore between the two orders of researches a distinction which is not a separation; but the distinction does, and always will, exist. The illusion consists in thinking that motion alone will be able to become the object of science, to the exclusion of the study of bodies put in motion. This idea would not deserve attention if it figured only in the writings of some philosophers intoxicated with Hegel's theory; but it made its appearance, a few years ago, in the prolegomena of a treatise on physiology. M. Beaunis affirms that there is no reason for distinguishing, as has always been done, the *mobile* or the body moved, and the mover or the cause of motion; but the motion, the body moved, and the mover, are reduced to one single thing—motion.[1] This author starts with the correct idea that matter is only known to us by its resistance or motion. Instead of concluding that the resistance constitutes for us the essence of matter, he concludes that "the body moved is reduced last of all to a motion." The mistake is strange enough to be taken note of. It is harmless, however, because the common-sense allotted to all men is found to be in accordance with the results of the most serious reflection, in confirming that thought

[1] "Nouveaux Éléments de Physiologie Humaine," Paris, 1876, pages 4 à 7.

of Pascal, reproduced and developed by M. Wurtz: "One cannot imagine motion without something which moves."[1] Let it be well understood, then, that when it is said that the system of modern physics reduces all the objective part of phenomena to motion alone, it is always understood that motion supposes a moving body; whence it follows that the study of the constitution of bodies will always continue as an essential part of the science of matter.

The Programme of Modern Physics.

The science of physics is a particular science of which the object is to explain the phenomena offered to observation by inorganic matter. It is placed, as has been already said, between the mathematics which furnish it with the means of explanations, and the biology to which it lends its information for the interpretation of the phenomena of life. It must begin with analysis in studying apart weight, heat, light, electricity; but, like every science worthy of the name, it causes synthesis to succeed to analysis; it brings together what at first it has distinguished. The doctrine of the transformation of motion comes to offer an experimental justification to that tendency of the human mind which is ever urging it to the research of unity.

In taking note of the results obtained, we must not blind ourselves to the fact that our system of physics leaves considerable blanks unfilled, and will leave such

[1] Pascal, "Pensées," De l'Esprit Géométrique. Wurtz, "La Théorie Atomique," livre ii. chap. iv. § 1 et 4.

blanks, no doubt, for a long time to come. The programme of the science is drawn out in its essential features, but many articles of this programme are marked with notes of interrogation. We do not know whether ether, supposing its existence absolutely demonstrated, is a special substance, or is only ponderable matter reduced to an extreme state of tenuity.[1] A mechanical explanation of the phenomana of cohesion and affinity is far from being solidly established. The existence of cold lights, as, for instance, that of phosphorescent bodies, raises, on the subject of the relations between the undulations of ether which are the cause of caloric sensations and those which produce luminous sensations, problems which, so far as I can ascertain, are not resolved, nor perhaps even stated in terms which allow a glimpse of the solution. In a more general way, How are the causes to be determined which, starting with the fact of a motion of ponderable matter, produce the various manifestations of heat, light, electricity? What is the initial form of universal motion? Is gravitation a primitive manifestation of the universal motive force? or has it an antecedent which reduces it to a phenomenon of impulsion? The question is an open one, since Newton, and gives occasion, in our days still, to opposite solutions, or to the expression of a prudent doubt.

To reach to the discovery of the laws which give account of the actual state of the terrestrial globe, of the solar system, and of the portion of the stars which come within the field of our possible observations,—

[1] Wurtz, "Théorie Atomique," livre ii. chap. iv. § 2.

this, to go no further, is a very elevated aim; and yet it does not include the whole programme of science. When we would give account of the *actual* state of the phenomena, the mind is led to the consideration of a state anterior to that which experience reveals to us. It is certain, or at least extremely probable, that the terrestrial globe has passed through a period of incandescence, and has gradually cooled down. The change has been accomplished, no doubt, through the effect of laws which are the object of the study of physics; but on the other hand, the result of the application of these laws has been modified by the very effect of the changes which they had provoked. Some astronomers reckon that we are able to contemplate in the depth of the heavens stars which are in course of formation by the condensation of the elements of matter. Following up these indications, we are led to a conception, due originally to an idea of Descartes, formulated by Kant, and afterwards by Laplace, and which bears the name of the hypothesis of the primitive nebulous matter.[1] Set forth at first with reference to the formation of the solar system, this hypothesis is susceptible of a more general application. In this highest degree of development it may be described as follows :—

The physical universe would have existed primitively in the form of diffused matter, distributed through space. The elements of this matter would have been subjected to the law of gravitation, which tended to bring them together, and to impulsions of another kind, which prevented their assemblage in a single mass.

[1] *De la nébuleuse primitive.*

Starting from this primitive condition, the universe was organised in the course of ages under the influence of the law of the communication and transformation of motion. It may therefore be conceived ideally that an intelligence acquainted with the disposition of the elements of the nebulous matter, and with the whole circle of the laws of physics, would have seen the actual universe in its germ, as a naturalist sees the plant in the seed from which he knows that it will issue.

To arrive at the determination of the primitive *nébuleuse*, of the nature of its elements, and of the initial laws of motion; then, starting from these data of fact, to deduce from them, by a mathematical synthesis, the organisation of the material universe—such is the loftiest and boldest aim of the complete programme of physics, in the general sense of that term. It is scarcely necessary to speak of the immeasurable distance which separates the present state of the science from the full realisation of this programme; but, following the actual direction of researches, we see all the lines converging towards a summit, inaccessible perhaps, but of which we may fairly admit the existence, even on the supposition that we may not be able to reach it.

The Inertia of Matter.

The five characters of modern physics may be connected with a doctrine which forms their common centre. This doctrine is that of the inertia of matter. We will begin by taking account of the value of two words—*matter* and *inertia*.

If it is asked what matter is in itself, a question is put to which, as to all questions of the same order, no answer can be given. To ask for the determination of a *thing in itself*—abstraction made of all its relations—is to make a demand contradictory in terms; for the knowledge which we can have of an object can never be anything but the result of a relation between that object and ourselves. But, in studying the manner in which the idea of matter is formed in our minds, it is easy to ascertain its essence; that is to say, the properties which suffice for the conception, and without which that conception vanishes. The fundamental idea of matter does not come from sight or from hearing, for the blind and the deaf possess it. We may take away the five senses (the feeling being limited to passive sensations, to the exclusion of the exercise of touch), and the idea of matter remains. Whence comes it? From the exercise of our motive power. From the moment we encounter resistance to our motion, even when there is neither light nor sound, nor heat, nor smell, nor taste, we conceive of the existence of a body. Foreign bodies are revealed to us by conflict with the motion of our own body, whether we touch them by a movement of which we have the initiative, or our organs react against the contact of a body which strikes against them. All the passive elements of bodies being taken away, and the motive power remaining, the idea of the body subsists. The motive power being suppressed, the idea of the body vanishes. If the passive sensations could subsist in this hypothesis, they would only be modes of our own

being, phenomena purely subjective, which would excite no idea of a foreign object, of a *not-I*.[1] The analyses of Condillac and Charles Bonnet, completed and rectified by those of Maine de Biran, have set this point of doctrine in full light. The idea of foreign bodies is primitively and essentially for us that of resistance to our organs, and the idea of the body proper that of a direct resistance to our effort.

The resistance of bodies manifests itself in space, and this resistance gives us thus the idea of a real shape, determined by the resistance itself. The conception of space is the necessary antecedent of the idea of matter, and therefore all the determinations of space which are the objects of study in geometry occur in physics; but the science of physics is distinguished from geometry, because the forms which it considers are real forms, resulting from the fact that the various parts of space are occupied by matter, while the forms treated of in geometry are purely abstract. We say, therefore, that the essence of bodies is to occupy a portion of space—to *occupy* it; that is to say, to offer resistance to the motion of another body. We generalise, in fact, the experimental idea of resistance to our personal effort, by extending it to the relations which bodies sustain between themselves.

This determination of the idea of matter offers a manifest analogy with the formula, often employed, which defines a body by the two notions of extent and impenetrability. But, the notion of extent remaining the same, the formula of the occupation of space, or of

[1] *D'un non moi.*

resistance, is preferable to that of impenetrability, because it leaves open the question whether the elements of matter have a fixed size, or whether their extent may be simply virtual. Boscovich affirmed theoretically, and Faraday believed that he had established by certain experiments, that the elements of matter are only centres of forces, and have not an invariable extent. In this hypothesis, an element of matter might possibly be compressed so as to be reduced to a mathematical point; that is to say, to a sphere whose radius is zero; but in the annihilation of its volume it would retain its proper power of expansion, so that its form, having remained virtual, would be realised as soon as the compression should be diminished. I have no intention of discussing this doctrine here. I merely remark that, in adopting the notion of resistance in space for the expression of the essence of matter, we leave open the question of the indefinite compressibility of the primitive elements of bodies—a question which is settled by the notion of impenetrability.

We may remark that the idea which we have arrived at by means of psychological observation is found to be in accordance with the results at which the theorists of mechanics arrive by another way. The idea of the mass is for them equivalent to the quantity of matter. Now, mass is defined as "a quality of bodies according to which they *yield* more or less easily to the action of forces;[1]" or — which comes precisely to the same thing,—as a quality of bodies according to which they

[1] Delaunay, "Traité de Mécanique Rationnelle," § 96.

resist more or less the action of forces. Mass has no other manifestation than resistance; and the two ideas of the mass and the quantity of matter being equivalent, the quantity of matter comes into question in mechanics only as the quantity of resistance.

The determination of matter is inseparable from the idea of motion, since resistance is conceived of only as opposed to motion. Time, which enters as an essential element into the idea of motion, becomes thus, in the same way as space, a necessary antecedent of the conceptions of physics.

The idea of force has its origin in the action which we exert upon our organs, and by our organs upon foreign bodies. If we take away the sense of an initial and free power, there remains the idea of a simple motive power. This power, separated from its immediate consciousness, is no longer conceivable than in the manifestation of its effects; and therefore force, as it is considered in physics, has no other determination possible than the motion which it can produce.

The resistance of a body which modifies the motion of another body manifests a force as well as a power of impulsion. A body in motion encounters another body; the state of the two bodies is changed in consequence; each of the two bodies, therefore, is a force in relation to the other, since it is the cause of a modification of the motion. Matter in itself, considered independently of its relations, cannot be defined, as we have said already. In considering a body in its relations with others, we define it as a force resisting in space motion which would tend to displace it, and constituting by that very

resistance a real force. "The force which resides in matter," says Newton, in the third definition placed at the commencement of his "Principia," "is the power which it has of resistance: *Materiæ vis insita est potentia resistendi.* It is this resistance which becomes the measure of all forces, impulsive and other, since a force is never determinable otherwise than by the motion which it can produce, or—which comes to the same thing,—by the resistance which it can overcome.

The name of *force of inertia,* habitually in use, has the inconvenience of employing in an active sense the passive term *inertia,* of which we are about clearly to define the meaning. The right designation seems to be *force of resistance.* Resistance is conceived of, whether in opposing motion in a body supposed to be at rest, or as opposing the modification of an acquired motion, which would continue such as it is but for the intervention of a foreign cause. If we suppose a motive force primitive and constant, all modifications of the motion result exclusively from the difference of resistances. Such is the essence of matter: the resistance in space which becomes a cause of the modification of motion in the relation of bodies between themselves.

And now, what must we understand by the term *inertia?*

Inertia, as the etymology of the word indicates, is a negation. It is the negation of all power proper to matter, beyond the single power of occupying space, and consequently of offering resistance. The passive part of this conception must not make us forget the

affirmation of the force of resistance of bodies which is the active and essential part of their idea. The general negation contained in the idea of inertia is developed in three particular negations:—

1. *There does not exist in matter any psychical element.*

The cause of a motion is never to be sought in the wills, inclinations, or desires of matter. If a stone falls, it is not that it has any affection for the ground; if a flame rises, it is not that it has any love for the sky; if water rises in the interior of a pump, it is not that abhorrence of a vacuum is one of the elements of nature. All psychological terms, such as those of attraction, affinity, &c. &c., are metaphors; and the first condition for penetrating the real nature of phenomena is to beware of taking literally this figurative language.

2. *There does not exist in matter any power to produce psychical phenomena.*

The sensations of light, sound, heat, result from a relation between the sensibility of organised beings and physical motions. In the explanation of phenomena we must never stop, therefore, at the idea of powers unknown and indeterminable appertaining to bodies; all explanations must refer to the geometrical consideration of forms, and to the dynamical consideration of motion actual or virtual.

3. *There does not exist in matter any power to modify its own motion.*

This negation excludes, not only every act of liberty

or caprice, but all element of spontaneity. A motion, whatever its origin, can never be modified by the action itself of the body which moves; so that all modification of motion supposes a cause foreign to the body itself which is under consideration. When two bodies meet each of them is force with respect to the other, since each of them modifies the motion of the other; this is the direct consequence of the power of resistance; but neither of the two bodies is force, with regard to its own motion. It is important to prevent all confusion between the active motion of matter which concerns the relations of bodies between themselves and the passive motion which refers to the state of a body considered by itself.

Such is the idea of inertia, and the development of the three negations which it includes. The two first negations have a wide bearing in philosophy. The third constitutes a law which lies at the foundation of mechanical science. M. Delaunay gives it as follows:—

"A body which is at rest cannot by itself set itself in motion.

"A body which is in motion cannot by itself modify its state of motion."[1]

The modification excluded by the second part of the law concerns only the direction or the velocity. A material point being in motion, says Laplace, "there is no reason why it should deviate rather to the right than to the left from its primitive direction."[2] Any modification which did not come from a foreign cause,

[1] "Cours Élémentaire de Mécanique."

[2] "Mécanique Céleste," livre i. chap. ii.

would entail the negation of inertia; and the sole direction which can be conceived as simple and constant, is the direction in a straight line. If the velocity of a motion were modified without the intervention of a foreign cause, the law of inertia would be destroyed also; for the slackening of the motion is an action,—it is an element of motion in a direction contrary to that followed by the body. A body in motion must therefore continue to move in a straight line and with a uniform velocity, so long as no foreign cause intervenes. These consequences are expressed as follows in the first law of Newton:—

"Every body continues in the state of rest, or of uniform motion in a straight line, in which it happens to be, unless some force acts upon it, and constrains it to change its state."

This law is the principle of all explanations in mechanics, but it does not answer to any fact which it is possible to take account of. The rest is only a semblance; all matter is in continual motion: the stars move in the sky; the molecules move in bodies which to us appear motionless. One might therefore, without inconvenience, suppress the first part of the law of inertia, and reduce the law to this simple formula: "Bodies do not possess any power of modifying their own motion." So expressed, and if we no longer suppose a state of rest which does not exist, the law no longer answers to any reality, because it supposes the motion of a body withdrawn from the action of every foreign cause; a supposition which places us outside the conditions of all possible experience. Rectilinear motion, when the result of weight, is an accelerated motion, and one which stops

when the body moved meets the ground: the motion of the stars, which goes on without stopping, is not a rectilinear motion. Thus it is, that the law of inertia escapes on all sides from the direct control of experience. To confirm it by direct observation, it would be necessary to be able to observe the motion without limit of an isolated body, a thing twice over impossible. It is a theoretical law; it is not surprising therefore that it has been attacked, and that it is attacked still in our days, in the interest of certain philosophical doctrines. The best answer to give is that inertia cannot be established by direct observation; but that, taking it as a principle for explanation, we arrive at results which experience confirms. This is the answer which Euler gave in his time to objections which still maintain their place in certain minds.

"However solidly established," he says, "be the truth of this principle—that every body, when set in motion, continues in the same direction and with the same velocity, unless some external cause comes to derange this motion—it is still attacked by some philosophers who have never made great progress in the science of motion; while those, to whom we are indebted for all the great discoveries which have been made in this science, are unanimously agreed that all their researches are based upon this principle." [1]

Nature does not present to us isolated bodies, but systems of bodies acting mutually upon each other. A system of bodies which communicate motion one to another—this is what is realised in a machine constructed

[1] "Lettres à une Princesse d'Allemagne," partie ii. lettre 5.

by men, and it is what is realised on a large scale in the solar system of which our earth forms part. The communication of motion by one body to another, gives occasion to difficult studies and complicated theories, in consequence of the diversity of the physical nature of the aggregates which come under consideration. This communication is effected, in an abstract and general way, in accordance with the law, that a body loses of its own motion only the part which it gives up to another; so that, according to the phenomenon of communication, the sum of the motions, actual or virtual, remains the same as before. If, in the transmission of motion, the initial motive force remaining constant, there were increase or diminution, it must be admitted that this variation would be produced without cause, or else that there exists a power of modifying motions in the bodies under consideration, which would be the negation of inertia. Hence it results, that attentive observation of a system of bodies which act one upon another, without the intervention of a foreign cause, will show that the sum of the motions must remain the same.[1]

It must be remarked, however, that, in the calculation, account must be taken not only of the actual, but also of the virtual motion, as we have already seen. Presented in this form, the law of inertia applied to a system of bodies approaches a possible experimental verification; still, the verification could not be absolute, because in the universe all hangs together.[2] A machine made by men cannot be isolated from all the natural

[1] Maclaurin, "Exposition des découvertes de Newton," p. 123.
[2] *Parce que tout se tient dans l'univers.*

causes which act upon it, and the solar system is subject to the action of the other stars which people space. The entire universe forms only one system of bodies; and, therefore, to verify in a complete manner the law of inertia, it would require a universal experience which absolutely exceeds the limits possible to man. But this law, though it is not possible that it should be confirmed experimentally, in an absolute manner, is very solidly established, since it serves as a base to satisfactory explanations of all observed phenomena.

The doctrine of the inertia of matter is the centre of all the conceptions of modern physics. It is easy to place before the reader the connection existing between this theory and the five characters above enumerated.

Inertia excludes from matter all power of its own, other than that which relates to the occupation of place and to motion; it therefore reduces the conception of bodies to mechanical elements: this is the first character.

From the exclusion of every property of matter which should not have relation to phenomena of motion, results the unity of matter as to its essential properties: this is the second character.

The diversity of physical phenomena can consist only in the divers manifestations of motion: this is the basis of the idea of the correlation of forces, or of the third character.

The negation of all cause capable of modifying motion, and inherent in matter itself, entails the constant maintenance of the effects of the universal motive force, if we consider that force itself as constant: this is the fourth character.

The mathematical nature of the explanations which forms the fifth character of the science, is attached, finally, to the idea of inertia by a close bond of connection, which it is of importance well to take account of. The mathematics study the different transformations of quantity. In its transformations the quantity remains the same; all the results of an operation are contained in its data; and every operation, to be possible, supposes that no term foreign to the data is introduced into the quantities under consideration. An error of calculation is a quantity improperly introduced. When mathematics are applied to physics, it is necessary, in order that the results may be found in accordance with the facts, that all the data be known. An error of observation, suppressing one of the real data of a physical problem, has the same result as an error of calculation. So it was, for example, that while the planet which has rendered the name of M. Leverrier illustrious remained unknown, the motion of the stars determined by observation was not found to be rigorously in conformity with the results of calculations to which that one of the requisite data was wanting. Now, it is easy to understand that a spontaneous act of matter, which it would be impossible to bring into the data of a problem, would produce exactly the same result as an error of calculation, or an experimental inaccuracy in the data. Suppose, for instance, five bodies, the reciprocal action of which is submitted to calculation, their masses and distances being given. If a sixth body, produced spontaneously, could intervene, or if the action of the five bodies could be modified

without the modification having any determinable antecedent, the application of calculation would be impossible. Kepler admitted, for an instant at least, in one of the excursions of his thought, that the planets might have souls. If it were admitted that these souls exercised only a motive action absolutely determined, and reducible to known formulæ—that is to say, that these souls were subject to the law of inertia—the supposition would not produce any confusion in science. But from the moment it was admitted that one of these souls, by will or caprice, could slacken or accelerate the motion of a star, it is clear that celestial mechanics would become impossible. The law of inertia, therefore, is the condition of the application of mathematics to the interpretation of material phenomena; and as the whole system of physics is in the way to be reduced to mathematical explanations, we may affirm that the law of inertia is more and more justified.

This law, which is the basis of physics, supplies the precise determination of the limits of this science. Treatises on mechanics exclude from the object which they have in view motion produced by a living being. The following are the motives of this exclusion, as they have been set forth by Biot:—

"One sole class of beings seems to form an exception to the law of inertia,—these are animated beings. But the material molecules which compose their parts are absolutely inert; when separated, they no longer live, but come under the ordinary laws which govern all other bodies. We are completely ignorant as to what

determines the condition of life; but, seeing matter under all other circumstances deprived of spontaneity, and aware that, even in living beings, it loses that faculty by death, we are led to regard it as foreign to its essence, and we conceive of the *will* of animated beings as the act of an internal and immaterial principle which resides in them. We cannot say in which of their parts this principle resides, or in what it consists, still less how, being immaterial, it can act upon matter; but we act philosophically in making the motion of animated bodies depend upon a cause foreign to their matter; since we find matter inert in all the other cases in which we are able to observe it."[1]

The rigour of philosophical language would require us to suppress the term *will* in this passage, which implies consciousness and free-will, and to replace it by another term expressing simply a principle of spontaneous motion. With this reserve, the words of M. Biot are the expression of a legitimate philosophical research, which attributes to different causes phenomena essentially different. Has any discovery been made, since the time this savant wrote, which warrants us in throwing any doubt upon the value of his conclusions? I think not; and what confirms me in my conviction is, that I have found M. Biot's words quoted with approval in a manuscript by a man thoroughly informed in modern science, and who has the advantage of being equally versed in the study of physics and in that of botany, namely Professor Thury. It is, therefore, a very bold affirmation, in a scientific point of view,

1 "Précis de Physique," tome i. page 21.

which is made by Professor Charles Martens, in the *Revue des Deux Mondes*,[1] when he says that "the abyss which existed between the organic and inorganic kingdoms, between brute matter and living beings, is definitively filled up," so that the physical and natural sciences, distinguished hitherto, form for the future "but one single science." To reduce to one single science biology and physics, it would be necessary to prove that living beings are produced by the simple combination of simple bodies. Now, M. Martens acknowledges that we "are ignorant as yet whether it is so;" that is to say, he declares that we do not know what his affirmation implies that we do know. In order that the abyss might be filled up, it would be absolutely necessary either to deny the law of inertia in its application to physics, or to proclaim that inertia is the law of living beings. It is allowable for a philosopher to give forth the opinion that science will one day arrive at this result; but to say that this result is already obtained, in the present state of experimental knowledge, is to misunderstand the requirements of a truly scientific method. We must maintain, till we have better warrant to do otherwise, that the inertia of matter, as opposed to the spontaneity of living beings, establishes between the physical and natural sciences a boundary, which those very persons who do not think it insurmountable must acknowledge to be as yet unsurmounted.

[1] 15 Décembre, 1874, pages 768 et 770.

LOGICAL CHARACTER.

Physics, like every other science of facts, is composed of hypotheses, which become laws more or less certain according to the degree of their experimental confirmation.[1] The science of modern physics, considered as a whole, is a grand hypothesis in course of confirmation. The explanation of the phenomena of heat and light by the undulations of ether, seems to be established upon solid bases; the existence of ether is a supposition rendered very probable by the explanations which it supplies. The relations which unite the agents formerly considered as distinct, and designated by the titles of light, caloric, electricity, and magnetism, are facts well established. The equivalence of mechanical work and heat has been established by numerous experiments; but the general equivalence of all physical phenomena is a thesis, the experimental demonstration of which is far from complete. In considering the action of the sun upon plants, no experience as yet enables us to determine the exact relation of the force of the rays and of the vegetable phenomena which must present their equivalent.[2] It results from these and other analogous facts that the total conservation of energy in the universe is not yet experimentally demonstrated, and one may say that, by the nature of the case, the demonstration will always fail of completeness. It may be asked, for instance, what becomes of the heat radiated by the sun. It is partly sent to the planets and the

[1] See, for the demonstration of this theory of method, the "Logique de l'Hypothese," 1 vol. in 8vo, Paris, 1880.

[2] Helmholtz, "Mémoire sur la Conservation de la Force," page 47.

other stars, and its terrestrial equivalent is sought in the physiological phenomena which fall within the field of our observations. They affirm, for example, without being able, as has just been said, to give certain proof, that the force of the sun is employed for the growth of wood, stored up in the trunk and branches of a tree, and that it is found again, wholly and entirely, in the form of light and heat, when the tree is consumed. But what becomes of the large part of the heat and light of the sun which radiates freely in space? Does it anywhere meet with a surface to reflect it, or does it accomplish a journey without end in the limitless extent?[1] The boldest minds would not venture a reply, and still an answer would be necessary to a complete experimental confirmation of the theory of the conservation of energy.

Inertia, in a word, that general basis of all physical explanations, is a hypothesis very much confirmed, but still a hypothesis. In fact, inertia is not a simple induction, the expression of a fact generalised. The duration of a motion increases in the proportion in which friction and the other passive resistances which may arrest it diminish. This is a certain matter of observation; but it does not necessarily lead to the idea of indefinite motion. Very good account would be given of the fact, by admitting that bodies have a natural tendency to rest—a tendency of which weight and friction increase the effect. No possible experience, as has been said, can show the indefinite continuation of a motion which no foreign cause comes to modify. Neither is it any the more the observation of the permanent motion of the

[1] Helmholtz, "Mémoire sur la Conservation de la Force," page 38.

stars which has led to the statement in form of the law of inertia. It was taught in the schools of the Middle Ages that celestial motions are circular and permanent, in contrast to terrestial motions, which are rectilinear and which stop. This way of conceiving of the phenomena was the result of a sufficiently natural induction. The law of inertia, which has not been established by induction, is not an *à priori* deduction either, like those of mathematics. The savants who stated this law for the first time did indeed establish at starting certain general principles; but these principles have not an immediate rational evidence, so that to consider inertia as a deduction would only be to put back by one degree its hypothetical character. This law is therefore neither an induction expressing a generalised fact of experience, nor a deduction from evident rational principles; it is certainly not an axiom; it can therefore only be an hypothesis. The law of inertia, says Laplace, either in his "Mécanique Céleste" or in his "Exposition du Système du Monde," is "the most natural and simple that can be imagined." Laplace here recognises the true character of the law; it has been "imagined," it is a supposition of the mind to explain the facts. It is simple, no doubt, as a means of explanation; but it is far from simple in the sense of a natural conception, which results from the mere application of common sense to the study of phenomena. It has, indeed, this character in its first part—everybody admits at once that a body at rest does not of itself put itself in motion. But that part of the law which is natural is precisely that which has no application in reality, since no body

is in a condition of absolute rest. The second part of the law—the indefinite prolongation of motion—is a supposition which is not natural, which, on the contrary, is bold to a degree, and very far removed from appearances. The law of inertia is therefore an hypothesis; but it is the best confirmed of all hypotheses in physics, because, as it forms the basis of all science, there is no progress in science which is not a confirmation of the doctrine which serves as its foundation.

To recognise the true logical character of modern physics is to avoid two errors—one in the domain of philosophy or of general science, the other in the domain of the science of physics itself.

Philosophical error consists in considering the laws which give account of experience, with various degrees of probability, as being absolute laws expressing the eternal and necessary nature of things. This error was natural at the time when it was thought possible to construct science *à priori*, by the mere study of the ideas of the reason; it is surprising to see it appear in the writings of authors who profess to belong to the experimental school. It is so grave an error that it is important to point out one of its sources in certain improprieties of language, to which sufficient attention is not given, and in regard to which I will go somewhat into detail.

M. Helmholtz says, in the introduction to his "Mémoire sur la Conservation de la Force" [1] :—

"The final object of the theoretical sciences is to find the constant causes of phenomena. The question

[1] Page 59.

here is not to decide whether all facts can really be reduced to such causes; that is to say, whether nature is always intelligible, or whether nature presents variations which, escaping from the law of a necessary causality, belong to the domain of spontaneity — of liberty. But we may affirm that science, which has for its object to conceive of nature, must admit the possibility of this conception; and it must, following up its hypothesis, pursue its work, if it were only to acquire the unquestionable certainty that our knowledge is limited."

Here is the legitimate expression of the nature of theories. They are hypotheses which must be followed into all their consequences, but with the fixed resolution to respect the facts which these consequences might contradict. The same author says, in his "Exposé de la Transformation des Forces Naturelles"[1]:—

"In observing all known actions, as well physical as chemical, one sees that the universe possesses a provision of disposable force, which can neither increase nor decrease. The quantity of force capable of acting, which exists in inorganic nature, is eternal and invariable."

Here the expressions become equivocal. The affirmation that the quantity of force can neither increase nor decrease is exact as the expression of the facts, in so far as it signifies that man cannot, by any mechanism whatever, create a quantity of force which does not exist; but if one applies the thought to the force itself, by affirming, in a metaphysical sense, the impos-

[1] Page 26.

sibility of its variation, one forgets the legitimate bounds of thought; and the employment of the term "eternal" only threatens to increase the confusion of ideas.

I have another remark to make of the same order. Mr. Tyndall, at the conclusion of his book on heat[1] says that "the power in circulation is perpetually the same." This is the legitimate expression of our experience; but when this author writes, "the law of conservation rigorously excludes creation and annihilation," the expressions he makes use of are dangerous for inattentive minds. The affirmation of the constancy of force involves the idea that neither the quantity of force nor the quantity of matter vary *in fact*. There is here not even a deduction, there is but a simple analysis of thought; but any one who denied creation in an absolute sense, in order to affirm the necessity and eternity of cosmical motion, would manifestly be transforming hypotheses explanatory of contingent facts into absolute verities.

I might here be accused of giving proof of a misplaced strictness, and of a kind of pedantry in the criticism of words and phrases. I do not think the reproach would be a legitimate one. Formulæ of language analogous to those which I have just pointed out place those who use them in danger of setting the mind on a wrong track, and of causing to be overlooked the experimental character of theories which could never claim to express an order of things absolute and neces-

[1] "La Chaleur considerée comme un Mode de Mouvement," Paris, 1864.

sary. Thus they become the occasion of serious errors. Improprieties of language, harmless in appearance, are dangerous in reality; because they lead certain minds, more inclined to synthesis than attentive to the rights of analysis, to make of physics the universal science, and so to destroy the foundations of moral order, by extending to humanity the idea of the mechanism of matter. It is therefore a duty incumbent on scientific writers to prevent, by the precision of the terms they employ, an error so grave as that which consists in considering the laws of physics as verities necessary in themselves, and universal in their application. This duty has been usefully discharged by M. Robert Mayer, in the address which he delivered to the German naturalists assembled at Inspruck in 1869. M. Mayer being the principal founder of the doctrine of the constancy of force, it would have been more excusable in him than in others to let himself be dazzled by his discovery; we must give him therefore full credit for the care with which he distinguishes three orders of realities—inert matter, life, and mind. To these three orders of realities apply three sciences, harmonised but distinct; whence it follows that mathematical physics, of which the domain is exclusively that of pure matter, is nothing more than an auxiliary science for physiology and psychology. Here are the illustrious savant's own words :—

"Let us pass from the domain of inert nature to that of living nature. While, in the first, we see the necessity and the application of the law, at its time always fixed, we see reigning in the second opportunity and beauty,

progress and liberty. It is numbers which mark the line of separation. In physics, numbers are everything; in physiology, they are but little; in metaphysics, nothing. Saturn, that god who devoured all, has ceased to reign; time is productive in our actual domain. God said: Let there be, and there was! We do not merely perpetuate the living world; that world grows, and improves in beauty. Let us take a step outside of dead nature, and seek, with calm reflection, to penetrate into living nature. We have to be on our guard against two errors. First of all, we must not neglect knowledge acquired in the domain of physics, when we penetrate into a new territory; we have rather in physiology and philosophy to call that knowledge to mind. The words of Plato, *μηδεὶς ἀγεωμέτρητος εἰσίθω*, must be applied to our subject. Physics, in the very widest sense of that term, that is to say, the science of inert nature in its entirety, must be considered, in the study of physiology and metaphysics, as an auxiliary science. In the second place, we must not rely too strictly upon physical data; for, while in physics we meet with laws, in the study of the sciences last-named we have but rules.

"The law of the conservation of matter and force finds equally its application in physiology. The living organism can neither generate nor destroy either matter or force; nor can it transform from one to another the chemical elements supplied to it; on the contrary, ternary and quaternary combinations are produced in the vegetable kingdom in the most marvellous way,—combinations which, oftener than not, cannot be obtained artificially. In short, in living nature are manifested a

generation and a production,—a sort of active energy, for analogy to which we should look in vain in the domain of pure physics. Therefore the proposition *ex nihilo nihil*, rigorously exact from a physical point of view, ceases at once to retain its strict force in physiology, and applies still less in philosophy. I remember on this subject a remarkable passage in the *Demonax* of Lucian. Questioned on the immortality of the soul, the philosopher replied, 'Yes, it is immortal like everything else.' The principle of conservation, or the second principle *nihil fit ad nihilum*, still retains a high value in the living creation of God, for it is not limited, as in dead nature, by the sterile proposition, *Ex nihilo nihil fit.*

"The French natural philosopher, Adolphe Hirn, who, with Joule, Colding, Holtzmann, and Helmholtz, discovered the mechanical equivalent of heat, admits the conclusion, which I think as true as beautiful, namely, that there are three categories of existences: (1) matter; (2) force; (3) the soul, or the spiritual principle. Once admit in principle that there do not exist only material objects, but that there are also forces, which, in the more restrained sense of science, are quite as indestructible as the matter of chemists, and there remains but one step to take in order to recognise and admit the existence of spiritual beings. In inanimate life, we talk of atoms; in animated life, we find individuals. The living body is not formed, as we know already, exclusively of material parts; it is constituted essentially by forces. But neither matter nor force can think, feel, and will; man thinks.

"For a long time it was generally admitted that the

spinal marrow, especially the brain, contained free phosphorus; and the imagination ascribed to this *free phosphorus* a great part in the operations of the mind. But the most recent and most accurate researches in organic chemistry have taught us that no living organism, and consequently not the brain itself, contains free phosphorus. Still, though such illusions must vanish before the results of exact science, it is not the less established that there are continually produced in the living brain material modifications, which are described as molecular activities, and the mental operations of each individual are intimately connected with this material cerebral action. But it is a gross error to consider these two activities, which are produced together, as being one and the same. An example will make this quite clear. We know that no telegraphic despatch can take place without the production at the same time of a chemical action. But what the telegraph says, that is to say, the contents of the despatch, cannot be considered in any way as a function of an electro-chemical action. The same may be said with still greater truth of the brain and of thought. The brain is only the instrument, it is not the mind itself."[1]

Without adopting all the opinions set forth in this remarkable passage, I only call attention here to the precautions taken by one of the founders of modern physics, that the functions of the mind may not be left out of view.

Without taking our physical theories for necessary truths, we are liable, if we forget their logical character,

[1] *Revue des Cours Scientifiques* du 22 Janvier, 1870.

to fall into another error, by considering them as the absolutely certain expression of a determined order of facts. In that case we think we have a right to deny, without troubling ourselves to examine it, every fact which might seem to make against these theories. At all periods of history, a great number of minds have been disposed to make of the science of their time a sort of infallible means of deciding what is possible, and what is not so. This tendency is far from being unknown to the savants of our own time. Numbers of facts have been affirmed by common opinion and denied by science. In many cases science was right, and it has been finally established that common opinion was a prejudice. In other cases it was science which was wrong, and the progress of observations has constrained it to register facts which it had denied, and to look for the explanation of them. This has been the case, for instance, with aerolites, the existence of which was long considered by the learned world as a popular notion unworthy of serious examination.

A theory does not allow of the denial of any fact, and must be abandoned from the moment that a fact solidly established contradicts it. Especially is it necessary to be circumspect when the investigation relates to living beings. All the laws of physics find their application in biology; but they apply under particular and often unknown conditions. Too much attention, therefore, cannot be given to the following passage from Claude Bernard, who, by authoritatively pointing out the place of hypothesis in science, has wished so to prevent the abuses of the systematic spirit :—

"Theories are only hypotheses justified by a number, more or less considerable, of facts. Those which are justified by the greatest number of facts are the best; but still they are never definitive, nor ought we ever to give them entire and absolute credit. . . . The great principle is, therefore, in sciences so complex and so little advanced as physiology, to be very little prepossessed with the value of hypotheses or theories, and to keep the eye always attentive to observe all that appears in an experiment. A circumstance, in appearance accidental and unaccountable, may become the occasion of the discovery of a new and important fact."[1]

The reserves of prudence, necessary in biology, are not less so in the study of inorganic matter.

M. Joseph Bertrand, giving an account of the contemporary revival of physics, complains that many minds are going too fast, and taking sketches, still confused, for finished pictures; he complains in particular that physics are being obscured by mathematical formulæ, and that so a misuse is made of a science the proper mission of which is to make all clear.[2] M. De la Rive, pointing out, with reference to the labours of Faraday, the march of contemporary science towards the doctrine of the unity of force, and of the transformation of motions, reminds his readers of the difference between a building in process of construction and one which is completed; and he writes:—

[1] "Introduction á l'Étude de la Médecine Expérimentale," page 290.

[2] "Renaissance de la Physique Cartésienne," dans le *Journal des Savants*, Juillet, 1870.

"Some of those who would popularise science, more eager to produce effect than careful to remain faithful to scientific truth, proclaim a molecular system of the universe destined, as they think, to make the pendant of la mécanique céleste of Laplace. According to them, nothing is simpler, nothing is clearer; attraction itself, which has been the object of study to so many superior minds, is nothing but the effect of an impetus easy to understand. A dangerous illusion—which, if it came to be propagated, would be as fatal to the true progress of science as contrary to its useful diffusion; for it is upon those who claim the honourable commission to bring science down to the people that the duty imperiously lies to spread only just and fruitful ideas."[1]

This "dangerous illusion" will be one no longer to be dreaded, when it is well understood that our system of physics is an *ensemble* of hypotheses confirmed to a certain degree, and not a science completely formed and certain.

To appreciate the import of these remarks, we must distinguish three elements in science taken as a whole —the experimental laws, the theories relative to the nature of the phenomena, and lastly the principles which direct the mind in the establishment of these theories. The experimental laws are the direct expression of facts; they may be stated without any confusion with theory. Thus, the laws of reflection, of refraction, of the dispersion of light, may be enunciated, and those who frame them may take neither one

[1] Notice sur Michel Faraday, dans les Archives des Sciences de la *Bibliothèque Universelle*, Octobre, 1867.

side nor the other as to the theory of emission or the system of undulations; and, in fact, these laws have been maintained under the successive reign of these two doctrines. The laws which simply express the facts—these laws judge of the theories, establish them, render them doubtful, or upset them. The theories, in their turn, provoke researches, suggest new experiments, discover new facts, establish new laws; and it is easy to show from history that to do away with theories would be to arrest the progress of science. Theories are sought for under the action of certain leading principles, of which the savant may or may not be conscious, but which, in either case, inspire his labours. Among these principles the most important is that of the order, the harmony, in other words, the unity, which is maintained in the midst of the diversity of the phenomena. Science progresses only by rising to laws more and more general, and by grasping among facts relations more and more extended; so it has been from the beginning.

"Nature rationally considered," says M. de Humboldt, "that is to say, submitted in its entirety to the operation of thought, is unity in the diversity of phenomena, harmony among created things, unlike as to their form, as to their peculiar constitution, as to the forces which animate them. . . . The most important result of a rational study of nature is the apprehending unity and harmony in that immense assemblage of things and forces."[1]

This result and conclusion of study is at the same

[1] "Cosmos," partie i. pages 3 et 4.

time its starting-point. M. de Humboldt recognises that the idea of the universal harmony, which presents itself at this day to the mind as the fruit of long observations, was primitively revealed to the inner sense "as a vague presentiment."[1] It is the same principle which appears in a confused way, as the motive of researches, at the basis of science, and which reappears at its summit, enlightened and confirmed, as the general result of discoveries.

This distinction between the three elements of science as a whole being established, we may ascertain the comparative value of these elements. What we are most sure of in our knowledge is the base and the summit; that is to say, the experimental laws, which are the immediate expression of the facts, and the general principle of harmony, of universal order, which is the expression, not of such or such a determined doctrine, but of science itself in its highest abstraction. The laws, when solidly confirmed, subsist, whatever the variations of theories. The discovery of the physical causes of gravitation would in no way modify the mathematical laws established by Newton; and ideas might vary as to the nature of electrical and magnetic phenomena without bringing the laws of Ampère into question in any degree. An accurate law is, just to the extent to which it is known to be accurate, a definitive acquisition. What subsists also, in all cases, and whatever may be otherwise the fluctuations of theories, is the generating principle of science, the idea of harmony to be sought in the diversity and multiplicity of facts.

[1] "Cosmos," partie i. page 2.

"The great mass of phenomena," says M. Helmholtz, "is being more and more reduced to order under the hand of science; doubts regarding the existence of immutable laws of phenomena are disappearing every day, and greater and more general laws are continually being discovered."[1]

The thought developed in these words is independent of any particular doctrine; it expresses the unquestionable result of the general development of science.

Between the base and the summit of our researches, between the experimental laws and the idea of universal harmony, lies the region of theories. Theories are variable and provisional, but the variations do not affect either the experimental laws when well established, or the guiding principle in researches. Theories have their day, and pass, but science remains; and since science is only the search for order and harmony, we may say that its principle is equally confirmed both by the birth of systems and by their destruction. The birth of a system manifests the need felt by the human mind to find an order which may account for the facts. The destruction of a system, arising solely from its insufficiency, invites the mind to search for a higher order than that which had been conceived. The spectacle of the rapid succession of theories which come to nothing, and are replaced by others, naturally awakens doubt; and to believe our present theories to be sheltered from the blasts which have overset so many others would be a strange fatuity. But the history of science,

[1] "Discours Prononcé à Inspruck," en 1869; et inséré dans la *Revue des Cours Scientifiques*, du 8 Janvier, 1870.

which makes us familiar with the overthrow of systems, shows us that to one system overthrown succeeds another, the conceptions of which are more substantial and of greater extent. It shows us that, notwithstanding some transient recoils, there exists a constant progress towards a higher comprehension of the universal order, so that the doubt, which may affect particular systems, becomes a confirmation of the generating principle of science. If we are not certain that we have discovered in its fulness the real order of nature, we acquire a conviction, continually more profound, that that order exists. The affirmation of the general harmony of phenomena which experience reveals to us is an anticipation of the mind. From the point of view of empiricism, it is a rash induction; in reality it is a natural confidence in the reason, and one which the results obtained are every day justifying more and more.

Experimental laws are the foundation of the arts and manufactures, which conduce to the improvement of our material condition. The idea of universal order lifts us to the conception of a supreme principle of harmony, and so is connected by an obvious link with our most elevated spiritual interests. The experimental laws subsist; the idea of universal order is gaining strength unceasingly. Variable theories, after having accomplished their mission, die out, just as provisional scaffolding disappears in the construction of a building.

The scientific hypothesis which constitutes modern physics has as its general result the reducing to unity phenomena considered by the ancient physics as

absolutely distinct. The discovery of Newton was a great progress in this direction. Contemporary science glimpses a loftier ideal in a law which shall embrace molecular phenomena, and the undulations of ether, as well as the motion of the stars. The rock on which thought is here in danger of splitting is the allowing itself to be dazzled by this splendid application of the principle of harmony, and the taking physics raised to this height as the expression of all reality, while the least philosophic culture suffices to show that the order of the motions of matter is but one of the elements of the universe, and the partial manifestation of a complete harmony into which enter elements of another nature. This manifestation, although partial, is so striking that it suffices to awaken feelings which give to science an æsthetic character.

Æsthetic Character.

The most ancient system of physics known to us was drawn up in verse. It is from fragments of lost poems that we learn how the Greeks explained, twenty-five centuries ago, the intermixture of the primitive elements, and the development of nature. The union of science and of poetry was easy at that time; because, on the basis of observations hardly yet commenced, the mind immediately started on its search after the universal harmony; and because ignorance of the facts allowed the creative imagination full play, and science in its infancy could blend, without any great effort, with conceptions of mythology. The study becoming more

serious, the scientific spirit made evident its requirements; it became necessary to bridle the imagination, to take away the sylphs from the forests and the naiads from the fountains, to deprive Neptune of the sceptre of the sea, and to unyoke the horses of the sun. Hence the prosaic character of a science which substitutes for graceful fancies the dull conception of matter and of the laws of its motion. The prosaic nature of science is derived again from causes more profound. Poetry, like painting, requires distances with outlines not strictly defined, and with which the sentiment of the infinite may be satisfied; all that is limited, weighed, measured, becomes prose. For a long time the earth sufficed for the poetic sentiment. It contained mysterious regions in continents unexplored; the seas offered to the imagination shores without bounds; the summits of the Alps remained inaccessible in their proud solitude; the Nile was not the only river to swell its waters in latitudes still unknown. But at this day the forms of the earth are known; all the continents are in process of being explored; the ocean is arrested everywhere by coasts whose outlines are marked upon our maps. Christopher Columbus, Magellan, Livingstone, the climbers of the Alps, the authors of geographical atlases, by chasing the unknown from the surface of the globe have shut out poetry. Natural philosophers and chemists, weighing, counting, and measuring, are accomplishing a similar work in their domain, by establishing the reign of abstract formulæ. And still this is not all. Poetry, which has need of the infinite, the unlimited, the unknown, has a like need of harmony, and delights in

the contemplation of unity. Now, the condition of progress in science is that we restrain the onward eagerness of thought as well as that of the imagination, and that we distinguish and separate. Science must continually beware of hasty generalisations, and be for ever applying lead to the human mind to prevent the beating of its wings. Science is therefore essentially prosaic. To experience the feeling of art we must forget science; to cultivate science we must proscribe the feeling of art.

All this is only relatively true. The science which arrives at such results, and which stops there, is an incomplete science. Geography banishes the infinite from the earth, but astronomy opens to it the skies: a boundless ocean is revealed in the universe of stars, with its unknown shores and its mysterious depths. The circuit of the earth is made, and we measure the circle which it describes about the sun; but the sun is moving in the measureless space with his retinue of planets; whither is he going? The effulgence of light, the magic of colours, all this is but the result of motion: this is prose, no doubt; but the motion of light is being propagated without ceasing; and as it starts from each world, it preserves the impress of all that has been. All the images of things are radiating through the limitless expanse; they keep indefinitely the lasting trace of all which is passing, and so triumph over the destructive power of time. All that has been visible upon the earth, even in some distant past, is visible now for some star or other in the heavens, and for beings whom we may suppose to be endued with adequate organs or

instruments. If our sceptical critics are mistaken, at the very time when they are contesting the historical reality of the oath of Grütli, there exists some world from whence might be seen the lonely meadow, the wave lapping the foot of the rock, and the light of the moon reflected by the manly features of the founders of Swiss liberty. On all sides are disclosed tracts of space without bounds; on all sides thought may lose itself in the infinite; the mystery reappears, only it is further off and higher. All this follows from the action of science itself,—follows directly from the questions of which it is the inevitable occasion; it destroys poetry on the one hand, but it reproduces it on the other. In presence of certain modern works, and expectation of the works of art which we may hope for, when a powerful breath of poesy shall pass anew over the world, Boileau might no longer bewail those modern ideas which banish the Tritons of the empire from the waters, and break the pipe of the god Pan. *L'infini dans les cieux;* those words, written by Lamartine over one of his songs, are the programme of a new poesy.

The observations of detail necessary to science veil the harmony and unity of nature; but this, again, like the destruction of the sense of the infinite, is a passing phenomenon; it is the condition upon which science subsists, and not science itself. Beams, stones, lime, sand, placed in separate heaps upon the ground, are the *condition* of a building. The majestic cathedral and the splendid palace will proceed from these shapeless elements, brought together by the genius of the architect; but these shapeless elements are not the building.

From the time that the scientific construction commences, and brings the materials into use, scattered facts are arranged in laws, particular laws are combined in more general laws, mutual relations come to light, and harmony is manifested. Science, by its proper development, re-establishes what it seemed to destroy; poetry re-appears transformed upon its heights; and, to those who can mount, it reveals itself in its glorious brightness. The natural philosopher, who, leaving aside for a moment the detail of experiments, contemplates the end to which all modern discoveries are tending, is moved by the sight, if he has not quenched in his soul all feeling of the ideal. The nature which he is seeking to explain realises in fact the two supreme conditions of art; she shows herself beautiful in her harmony, and sublime in her immensity. In all departments of the development of the human mind there is encountered a dull intermediate space which must be crossed to come again into the light. And between the first impulse which urges them to the search for beauty, and the actual production of works of art, have not the painter and the musician to wade through the prosaic dreariness of material processes? All who have been among the mountains know the fog which often rests upon the middle region of the Alps, and so lies between the plain which is clear of mists below and the summits bathed in light. The great mistake is to be stopping midway in the ascent, and concluding that, because it has been necessary to mount in order to reach the obscure region, therefore the fog occupies the summit of the universe.

So long as we continue in the study of details, there is no possible agreement between science and poetry. A ray of the morning sun lighting up a dewdrop upon the cup of a flower may awaken a world of ideas and feelings; but one would not advise an observer to choose such a moment in which to employ his thoughts upon the phenomena of cohesion, of weight, or of radiating heat. Nothing is more intolerable than the pedantry of a student who, surrounded by the splendours of nature, insists upon giving you the benefit of the instructions of his professor of physics, just as it would be a stupid impertinence to be reminding a man who was enjoying a delightful piece of music of the number of vibrations which went to make each note.

So long as we stay in a fragmentary consideration of phenomena, the order of science and the order of poetry are not only distinct, they are opposite; and the savant must at times consent to forget what he knows in order to taste with the ignorant the joys which nature lavishes upon all. But these two orders are opposite only as are two faces of a pyramid, which approach one another as they rise and join at the summit. A drop of water reflects the rays of the sun; it absorbs also its heat; and the heat evaporates it, as it had raised the waters from the ocean which fall again as rain upon the ground. By the action of light and heat plants are developed, and by the same influence also is developed the insect which comes to sip the dew. The same sun which enlightens and warms the earth is the agent of the universal circulation of life: plant, insect, sun, all are bound together in a supreme and harmonious

unity. Does not the drop of dew, of which a partial science destroyed the charm, shine now with a high poetry, while it reflects the rays of a thought more complete and higher?

All the great advances of science have been accompanied by a development of æsthetic sentiment. M. De Humboldt draws attention to the grace and poetic elevation of some of the language in which Copernicus set forth his discovery:—

"In the magnificent temple of nature, who would have that lamp suspended in any other place but that from which it may throw its light upon the whole? From his royal seat the sun governs all the family of stars which move around him. We thus discover in the world of things an admirable symmetry, and in the grandeur and motion of the stars a harmony which is found in no other way." [1]

There is poetry also in the fervid utterances of the piety of Kepler:—

"Happy, happy are they to whom it has been given to lift their minds towards the heavens; they learn to place little value on what had appeared to them excellent, to esteem above all things the works of God, and to find in their contemplation a true enjoyment and a real joy. . . . I give thee thanks, O Lord, that thou hast permitted me to rejoice even to ecstasy, in the contemplation of the works of Thy hand. . . . Great is our Lord! Sky, sun, moon, and planets, proclaim His glory, be the language what it may by which ye are able

[1] "Cosmos," ii. pages 371 and 592; see also Rougemont, "Histoire de l'Astronomie," page 85.

to express your adoration! Proclaim His glory, ye celestial harmonies! . . . And thou, my soul, chant the glory of the Eternal through all the duration of my existence!"[1]

The grandeur and simplicity of the laws of nature, revealed by the discovery of Newton, excited men's imaginations, and produced in their minds a genuine enthusiasm, of which the verses addressed by Voltaire to the Marquise du Châtelet are a very feeble expression.

The full development of modern physics rests, as we have seen, upon the two essential ideas of the correlation of motions and the constancy of force, ideas which realise, in a degree unknown till now, the thought of harmony.

"It appears to us difficult to conceive," says M. Marc Dufour, "that the man who obtains a glimpse for the first time of the new principle should not be struck with admiration in presence of so much grandeur and simplicity."[2]

Here presents itself, under another form, a danger which we have before pointed out when discussing the logical character of science. The logical error consists in taking the harmony of material phenomena for the supreme harmony of all existences; the æsthetic error consists in allowing the most elevated feelings of the soul to waste themselves upon this inferior part of the universe. After pointing out the action of light and heat in the phenomena of life, M. Helmholtz jocularly says, that "we may all lay claim to the same nobility

[1] Rougemont, "Histoire de l'Astronomie," pages 88 et 89.
[2] "La Constance de la Force," page 22.

with the Emperor of China, who calls himself the Child of the Sun."[1]

M. Virchow speaks of the action of the sun as being, not the condition of our development, but "the cause of our existence."[2] A French writer, a while ago, in a widely-circulated publication, penned a passage in which the sun is called "our heavenly father." If the influence of positivism should continue to spread among savants the religious sentiment and the philosophical spirit, then the need of adoration, of which man cannot rid himself, would find its object in the marvellous mechanism of which modern physics are revealing to us the secrets—we should return to the adoration of nature, and the sun would again become one of the great gods. The supposition may seem extravagant; but we must not forget that Auguste Comte, the founder of positivism, came at last to number the sun and the moon among the beings towards which modern man, set free from the superstitions of the past, is specially to direct his homage and adoration.[3] But we will have done with these real though strange aberrations, and go on to observe the æsthetic feeling of nature, when kept within reasonable limits. Mr. Tyndall, at the end of his book upon heat, writes as follows:—

"Presented to our minds in their true aspect, the discoveries and generalisations of modern science constitute the most sublime poems which have ever

[1] "Mémoire sur la Conservation de la Force," page 47.

[2] *Revue Scientifique* du 16 Mars, 1872, page 888.

[3] "Synthèse Subjective," pages 24 et 25.

been offered to the intelligence and imagination of man. The natural philosopher of our day is unceasingly in contact with marvels which would throw those of Milton into the shade; so grand are they and so sublime, that the man who has to do with them requires no little strength of mind to prevent his being dazzled and bewildered by them."

Without accusing this author of wanting strength of mind, we may be allowed to think that when he approaches the high generalities of science, some symptoms of bewilderment do manifest themselves in his thoughts. But without, for the moment, discussing his philosophical views, let us remark the particular form in which he expresses the feeling which the results of science awaken in his mind. With reference to the constancy of force he writes thus:—

"This law is the unlooked-for generalisation of the aphorism of Solomon: *There is nothing new under the sun;* in this way, that it teaches us to recognise everywhere the same primitive power in the infinite variety of its manifestations. The power in circulation is perpetually the same; it rolls in floods of *harmony* across the ages."[1]

We see that the æsthetic impression takes here the musical form. The mythological poetry of nature, disposing of the divinities of the waters and of the forests, could manifest itself by means of painting; but the poetry which is connected with the series of laws and the harmony of nature, could only find expression in music. The form given by Mr. Tyndall to the mani-

[1] "La Chaleur Considérée comme un Mode de Mouvement," page 427.

festation of his feeling is not an isolated fact. M. Oswald Heer, to express the emotion occasioned by the spectacle of the successive phases of the creation, in which is displayed so strikingly the plan of an infinite wisdom, compares it to the effect produced by a sonata of Beethoven.[1] Leibnitz said: "The beautiful harmony of the verities one meets with all at once in a regulated system satisfy the mind much more than the most agreeable music."[2] Before Leibnitz, Kepler, looking for a term which should answer to his feelings, entitled one of his principal works the "*Harmonies* of the Universe;" and, more than twenty centuries before Kepler, Pythagoras, who placed in the front rank in his school the mathematical sciences and the art of music, heard, as says the legend, the sound which the celestial spheres give forth as they move through space. The ideal after which science aspires is like a melody, Plato would have said, of which the human soul possesses a primitive intuition—a vague reminiscence. This melody, marred by rude instruments, disfigured by the mistakes of the players, finds, in proportion as science progresses, an expression less and less imperfect. The science of physics finds one of the elements of the universal harmony in the agreement of the motions of matter; but if, by a difficult effort of abstraction, we could succeed in separating motion from its laws, and the laws from the relations which unite them, so as to have in view the mechanism only, all the magic and charm of the

[1] "Le Monde Primitif de la Suisse," page 771.

[2] "Discours touchant la Méthode de la Certitude," Édition Erdmann, page 175.

universe would disappear; and, as in the dream of Racine's *Athalie,* there would remain nothing but "a mingled heap of horrid limbs to view!" It is the contemplation of the ideas and of their mutual relation which establishes the necessary bond of connection between the motion perceived by our senses and artistic emotions. So it is that the great spiritual functions —perception by the senses, intelligence, and feeling— present a correlation which is not less admirable than that of the material phenomena.

It must never be forgotten that general theories, and the sentiments to which they give rise, have no value except so far as they rest upon bases of fact solidly established. Chemical action prepares obscurely in the pile the dazzling light of electricity: in order to the success of the operation, none of the conditions of the experiment must have been neglected. From the study of inert matter, the object of the natural philosopher, shoot forth streams of light, brilliant, and sometimes sublime. But that these lights may not be deceitful, the thoughts which produce them must proceed from a humble and patient study of the reality. The most elevated emotions of the soul have a legitimate place in the exposition of scientific results: to wish to be rid of them would be próof of a narrow mind. But the beauty of science is not of the same order with that of the artist's ideal creations. Experience must keep all its rights, reason must preserve its undisputed sway. It must not be that rash generalisations and false analogies, the fruits of a heated imagination, make turbid the springs of study. In the domain of art, the

feeling of beauty is the base of all the work of the creative imagination; in the domain of science, the feeling of beauty can only be the crowning of the labour of thought—labour which must be accomplished under the exclusive control of experience and reason.

SECOND ESSAY.

Origin of Modern Physics.

THE ancient system of physics was still generally taught sixty years ago. At that time the existence of different forms of matter endowed with specific properties was admitted as an explanation of phenomena. It was as follows that Auguste de la Rive, addressing the Société Helvétique des Sciences Naturelles, assembled at Geneva, on the 11th August, 1845, gave account of the conception which founded the science of modern physics :—

"It rests," he said, "upon the notion of the existence in the whole universe of an ethereal matter, exceedingly subtile, perfectly elastic, in which are suspended and float, so to speak, the atoms of ponderable matter. To exert upon one another a mutual attraction, to occasion, in that ethereal substance by which they are surrounded, undulations more or less intense, more or less rapid, such would be the function of the heavy atoms which, grouped under the form of solids, or liquids, or gases, would constitute bodies. All the phenomena of radiation,—light, radiating heat, chemical radiations, are then only the effect of these undulations

Guericke (1602 to 1686), after inventing the pneumatic machine, ascertained that sound is not transmitted in a vacuum, and so proved experimentally its real nature. This discovery afforded the basis of an induction, by which the cause of sensations of light and heat was sought in phenomena of undulation. De la Rive, presiding again at a meeting at Geneva of the Société Helvétique des Sciences Naturelles, on the 21st August, 1865, pointed out the influence exerted in the formation of modern physics by the discovery of Fresnel, that light is the result of a motion; and the discovery by which Oersted showed the connection existing between electricity and magnetism. What he did not say, but which M. Dumas said of him in his commemorative discourse at the Institute,[1] was that he himself brought an important contribution to the same scientific movement by the discovery of the chemical antecedents to the production of electricity. After the mention of the labours of Fresnel and D'Oersted, De la Rive concluded as follows: "This was the double starting-point of numerous labours which, issuing in our days in the mechanical theory of heat, have led to the discovery of multiplied relations between the different physical forces, and to the substitution, in the idea which we must entertain of their nature, of the notion of motions for that of distinct agents. We can even already obtain a glimpse of the time when they will come to be looked upon as merely modifications of a single force, and when a new Laplace will be able, as

[1] Éloge Historique d'Arthur Auguste de la Rive, lu dans la Séance Publique de l'Institut, le 28 Decembre, 1874.

the author of the "Mécanique Céleste," has done for the phenomena of the heavens, to reduce to the laws of simple mechanism all the phenomena of inorganic nature."

This passage contains the complete programme of modern physics as it has been set forth in our First Essay. We will recall its essential features: To have recourse for the explanation of phenomena to specific properties of different forms of matter—this was the ancient system of physics. To explain all by means of the conception of the motions of a matter, one in its essential properties—this is the modern system. With the fundamental idea of the mechanical nature of the phenomena are connected two important theories—the inertia of matter, which is a force of resistance in space, but possesses no power to modify its own motion; and the conservation of energy. Ancient physics held the notion of a waste of force in the relations of bodies between themselves. This idea is foreign to present science, which reckons that, in the various transformations of motion, the sum of actual or virtual motion remains the same. The savage succeeds in kindling a fire by rubbing together two pieces of dry wood. In this process, as understood by the ancient system, there were three distinct elements—motion, the caloric fluid, and the luminous fluid. According to modern physics, there exists but one sole element—motion, which is mechanical in the friction of the two pieces of wood, molecular in the interior of the wood, etheric in the undulations which produce upon our senses the impressions of light and heat. It comes to this, then, that

the whole science of physics is the science of mechanics, and that of mechanics, according to the definition of Carnot, is nothing else than the science of the communication of motion.[1]

De la Rive, in his speech delivered in 1865, makes the year 1815 to be the date of the new direction given to the march of science; but, in his speech of 1845, he had stated that the new idea was connected, through the medium of Euler and Huyghens, with the theories of Descartes. In fact, the conception of modern physics is not new but renewed. The nineteenth century is furnishing by degrees the experimental confirmation of it, but the theory belongs to the seventeenth century, and, in the seventeenth century, it belongs more especially to Descartes, who is, not in an exclusive way, but *par excellence*, the founder of modern physics.

The solidarity of intellects in the progressive conquest of truth is a fact above discussion. A discovery has almost always antecedents which take from it its character of sudden novelty. Often it is made by several minds at once. It is a mistake in the history of science, as well as in that of societies, to ascribe everything to individuality; but it is not less a mistake not to appreciate the value of individuals, and to attribute all to I know not what occult and impersonal power called the spirit of the times, or the general current of thought. This general current exists assuredly; but if we go back to its sources, and to those of the affluents which feed it, we come at last always and necessarily to personal thoughts. The man

[1] "Principes Fondamentaux de l'Équilibre et du Mouvement."

who discovers an idea and discerns the consequences of it, deserves the title of inventor, even when others have seen the same thing as he. The man who effectively gives extension to a new idea, and succeeds in making it the basis of a scientific construction, receives legitimately the title of founder. Those who come after him correct and complete his work, but the work remains his own. For the general conception of the material universe, Descartes is at once inventor and founder. It is long ago since, braving a widespread prejudice, M. Bouillier affirmed, in his "History of the Cartesian Philosophy,"[1] that Descartes merited the title of father of physics. M. Renouvier makes the same assertion in an essay in the *Critique Philosophique.*[2] The following pages, if the accuracy of the data which they contain is admitted, will go far to justify these affirmations.

The mathematical and metaphysical discoveries of Descartes constitute his chief glory; but he himself informs us, at the end of his "Discours de la Méthode," that the essential object of his labours was such a knowledge of natural phenomena as might alleviate the sufferings of humanity. "I have resolved," he says, "to employ what time there remains for me to live in nothing else than in endeavouring to acquire some knowledge of nature such that from it may be derived rules for medicine more certainly efficacious than those which have been in vogue hitherto." In his work, "Principes de la Philosophie," metaphysics occupy an important place; but it is intended to serve for pro-

[1] The first edition is that of 1843; the third of 1868.

[2] 5 Février et 5 Mars, 1874.

legomena to physics, and the physics were to be an introduction to medicine. In physics, Descartes made some discoveries of detail: the law of the refraction of light bears his name: the discovery of the effects of the weight of air, attributed to Toricelli and to Pascal, appears to belong to him also.[1] He occupies, therefore, a place of some importance in the history of the experimental part of science; but this is not his great title to the gratitude of posterity. It is in the general theory of material phenomena that he has especially displayed his genius. In order well to understand his work in this respect, we must ascertain what was in his time the state of the science of physics.

State of Physics towards the Year 1600.

I will explain the theory generally accepted towards the year 1600, taking for basis the physics of Scipio Dupleix, a work published at the time when Descartes was still a child, and with which he might have been acquainted while pursuing his studies.[2]

Dupleix, setting forth the opinions taught in the scholastic philosophy, explains all corporeal phenomena by means of three elements: matter, form, and motion.

The matter of which he speaks is thus defined, after Aristotle: "The first subject from which, in so far as it

[1] "Le Cartésianisme," par Bordas Demoulin, tome i. pages 308 à 312.

[2] "La Physique ou Science des Choses Naturelles," par M. Scipion Dupleix, Conseiller du Roi, 1 vol. in 12. The work bears no date, at least in my copy; but it is, I suppose, a part of Dupleix's "Course of Philosophy," published in 1602, when Descartes was six years old.

abides, all things take their rise of themselves principally and not by means of others." The author observes that this conception must seem "obscure to novices,"[1] therefore he explains it. His explanations come to this: The primitive and unique matter, of which all things are made, is substance in general, that which exists under the properties of things, that is to say, since all determination expresses a property, being undetermined and indeterminable.

The matter of all things being the same, whence comes the diversity of beings? From the diversity of forms. It is not a question here of the figure or the form in the geometrical sense, but of what makes a thing to be what it is. Forms so understood are conceived as entities which receive the name of *substantial forms* and also that of *real qualities*. Water and fire, for instance, have the same matter since the same matter is the being of all that is; their difference comes from the fact that, in one case, the matter is specified by the form of fire and in the other by that of water. All the diversities of things are thus connected with different principles conceived as the explanation of the phenomena. Heat, cold, light, opacity, colours, taste, smell, liquidity, fluidity, exist by virtue of substantial forms joined to matter, and without which the matter would be indeterminable. Absolute weight and relative weight, absolute lightness and relative lightness, are real qualities which explain the motions of bodies. The existence of qualities as distinct entities is so fully accepted that it serves for premises to various reason-

[1] *Obscure aux apprentifs.*

ings. Dupleix, for example, takes to task "certain new doctors or doubters, destroyers of things Divine and human, who call into doubt the number of the elements, —nay, who do not even recognise one of them, and this against the ancient and approved doctrine of all the great personages of all past ages, since philosophy has been in vogue." Against these he wishes to prove that there exist four elements. The first proof of his thesis is the following: "Just as there are four primary qualities, heat, cold, dryness, and humidity; so they must have each one its proper subject. Now it is certain that they cannot be more proper to any other subject than to the four simple bodies which we call elements—namely, heat to fire, cold to water, dryness to the earth, humidity to the air. It must be said therefore that there are four elements, neither more nor less." We see that the reality of the four elements is inferred from the reality, held for incontestable, of the four qualities.

The facts of inorganic nature and those of life were involved in the same system of explanations. The substantial forms became vegetative souls in plants, and sensitive souls in animals, or rather the souls, in a way of diminution, became in physical bodies simple substantial forms. It was, by a reverse of the attempt of certain moderns who are endeavouring to constitute a biology purely physical, an attempt to account for the phenomena of matter upon biological principles. It resulted from this way of looking at things that psychical attributes were ascribed to substantial forms. Bodies had antipathies and sympathies, which revived the ancient doctrine of Empedocles. The

form of water was hostile to that of fire; the form of humidity was hostile to that of dryness; a body set in motion stopped because it had a love for rest; the abhorrence of a vacuum, or, what came to the same thing, the love of continuity, served for the explanation of the phenomena. We must not exaggerate the import of this mythology, in which we must make allowance for the forms of language. The abhorrence of a vacuum attributed to nature, the love of rest attributed to bodies, were formulæ which grouped together a great number of real facts. The mischief lay in taking the figurative expression of a group of facts for a principle at which research was arrested.

Motion was the third principle of explanation. Dupleix, with the School, defined in terms borrowed from Aristotle: "Movement is the act of the thing which is by power in so far as it is by power." The definition is not easy to understand, and as Descartes declares that he could not understand it in French any better than in Latin,[1] we need not be ashamed to make the same avowal. In reality, by motion was understood all change of what kind soever: generation, corruption, accretion, diminution, alterations of every sort. What we now call motion appeared, under the title of *local* motion, as one of the species of a genus. What proves how greatly the meaning of the word differed from that which we attribute to it, is that the existence was supposed of a great number of motions which may be accomplished "without any change of place in the bodies."[2] As to local motion, or change of place, it

[1] "Le Monde," chap. vii. [2] *Ibid.*

was supposed that it was divided into several kinds inherent in various forms of matter. The sky had naturally a circular motion; heavy bodies a rectilinear motion which caused them to descend; light bodies a rectilinear motion which caused them to ascend. These three sorts of motion were considered permanent. Then came violent or forced motion, that, for instance, which the hand of man communicates to a body. It was thought that this motion would stop immediately, by virtue of the tendency to rest, or active inertia, without the influence of intermediate causes. A body being thrown into the air, for example, it was thought that the air which it displaced folded in behind it, as water behind the stern of a ship, and pushed it forward, for some time still, after the moment when it had received the impulse, until the love of rest prevailed.

These theories were obscure and complicated. Their complication went on increasing, in proportion as it became necessary to explain fresh facts, just as the fancied circles in the astronomical theory of Ptolemy were indefinitely multiplied. A great many minds were sensible of the deficiency of a science so constructed. They waited for chiefs who might lead them on resolutely to the attack upon the teaching of the School. They had several such leaders, of whom Descartes was the principal.

WORK OF DESCARTES.

The centre of the work of Descartes is the destruction of the substantial forms, which, as he himself puts it, "can be with more difficulty known than all the things

which it is pretended to explain by means of them."[1] He distinguishes the ideas, or, as we should say now-a-days, the sensations which material things excite in us, from the causes of those sensations as they exist in the objects themselves. We receive the impression of heat and that of light. This impression is received by our soul; but we are not to suppose that luminous bodies see, or that bodies which send us heat themselves feel hot.[2] There is here a relation between corporeal phenomena and the mind, a relation which is produced when the sensible impression derived from the external world has been transmitted by the nerves to the cerebral centre, which is the point of union of the soul and the body. To make of heat, light, colours, sound, distinct entities, is to take simple relations for beings. Substantial forms, or real qualities, are realised abstractions which explain nothing, but "which themselves have need of explanation."[3] Let us not attribute to bodies properties the idea of which we form in ourselves. Why does not wine flow from the single opening in a barrel otherwise hermetically closed? "It is to speak improperly to say that that takes place for fear of a vacuum. We know well that wine has no intelligence to fear anything; and even if it had, I know not for what reason it should fear that vacuum, which is, in fact, only a chimera."

If the various qualities of bodies depend on causes unknown and indeterminable, science is not possible. If science is possible, it must be that the various qualities

[1] "Les Principes de la Philosophie," iv. 201. [2] *Aient chaud.*
[3] "Le Monde," chap. v.

of bodies result from something which it is possible to determine. Now what is it that we are able to ascertain in the nature of bodies? That which we shall be able to conceive of clearly, if we put aside our prejudices, our imaginations, our combinations of ideas, which may be false, in order to confront frankly the essential laws of the reason. Our clear and distinct conceptions are true. This is the fundamental principle of Descartes' philosophy, a principle which as good as says that the world is rationally organised, or, in other words, that there exists a harmony between our thoughts and the reality. If it is not so, science is impossible; if science is possible, then it is so. Descartes seeks, therefore, for such clear and distinct conceptions as we may have of material phenomena, isolated from their relations with beings capable of feeling. He bases his system of physics upon the consideration of these three elements, matter, form, and motion. They are the same elements as those of the physics of the School; but, as we shall see, the same terms are taken in very different senses.

There exists but one sole matter; but the question is no longer here of the indeterminate being which may become indifferently body or soul; we are concerned only with body. We are able, in our thought, to take away from a body heat, colour, weight, and other qualities of the kind; "for if we examine any body whatever, we are able to think of it as having none of these qualities, and still we know clearly and distinctly that it has all that makes a body, provided it have extension in length, breadth, and depth."[1] To

[1] "Principes," ii. 4.

occupy space,—this, therefore, is the essential property of matter. It is no longer the indeterminate being of which one has nothing to say, but a determined nature which may become a principle of explanation. Descartes admits that matter, one in its essential qualities, is divided into three elements, which form the basis of his natural philosophy. What is important to remark, without entering into these details, is that he admits the existence of a fluid, universally diffused, which he compares to "a liquor the subtlest and most penetrating in the universe,"[1] in which the other elements of matter are plunged, and which plays an important part in the phenomena of motion.[2] He would not have one brought to a stand by the notions of those men "whose reason does not extend beyond their fingers, and who think that there is nothing in the world but what they touch."[3] He would not that one should doubt that there are bodies "so small that they cannot be perceived by any of our senses."[4]

Matter being one in its essence, whence comes the diversity of the elements and of their components? From form and size. Form is taken here in its purely geometrical sense; the diversity of things comes from the different shapes of the elementary parts of matter, and from their various aggregates.

Motion is the third principle of explanation; but the idea of motion is precisely defined, as have been defined the ideas of matter and of form. Motion is "the transporting a part of matter or of a body from

[1] "Le Monde," chap. v.
[2] "Principes," ii. 59.
[3] "Le Monde," chap iv.
[4] "Principes," iv. 201.

the neighbourhood of those bodies which immediately touch it, and which we look upon as at rest, into the neighbourhood of some others."[1] Here we have the definition of motion, and the mention of its relative character. We cannot conceive of the motion of a body except in its relation to another which we regard as motionless with respect to it, though the latter may itself be in motion with respect to other bodies. When a body moves, "it passes from one place to another, and occupies successively all the spaces which are between the two." This conception is so elementary and primitive that geometricians explain "a line by the motion of a point, and a superficies by that of a line."[2]

This local motion is the real origin of all the other motions admitted by the School; every phenomenon of accretion, dissolution, or transformation can take place only by a movement of corporeal parts.

Descartes denies the primitive diversity of motions, as he denied the primitive diversity of the properties of matter. There exists one sole primitive motion which always tends to accomplish itself in a straight line; from this motion, primitively and naturally straight, result in effect motions in curved lines, by reason of the resistance of bodies and of their various forms.[3] The variety of motions results thus from the diversity of bodies, and, on the other hand, every change in the form of bodies has motion for origin and cause.

[1] "Principes," ii. 25. [2] "Le Monde," chap. vii.
[3] "Principes," ii. 39.

Physical phenomena, regarded in an objective way in the bodies themselves, comprise nothing more than motion. All the rest—colours, smells, sounds, and all the other sensible qualities—are relations between motions of matter and spirit. These relations result from a twofold adaptation—that of the living organisms to physical motions by the apparatus of the senses, and that of modifications of the soul to motions of the cerebral apparatus, in which come to meet, by means of the nerves, the impressions received by the senses. Thus it is that Descartes, distinguishing the two elements of a relation, matter and spirit, shatters the realised abstractions out of which the school had made quite a mythology of substantial forms, real qualities, virtues, &c. All the material universe becomes merely "a machine in which there is nothing at all to consider but the forms and motions of its parts."[1]

The import of this scientific revolution was immense. In the stead of unknown properties, undetermined in number, occurring for each order of phenomena, and arresting researches continually before causes held for real and declared occult, forms and motions became the one sole object of science. The relations of the soul and the cerebral centre remain a primitive fact, the explanation of which cannot be attempted; but for the physical phenomena in themselves, all explanation must be sought in mechanical conceptions perfectly clear, inasmuch as they go on finally to resolve themselves

[1] "Principes," iv. 188.

into mathematical data and formulæ. Let us follow out, in a few of its applications, this fundamental thesis.

Descartes maintains the opinion, still contested in his time, that sounds are vibrations of the atmosphere. This is a truth to which he adheres without having been the discoverer of it; but what belongs to him as his own is this: He affirms that it is "motion alone which, according to the different effects which it produces, is called at one time heat, and at another light." This is how he proves it for heat: "By merely rubbing the hands together one warms them, and any other body may also be warmed without being put near the fire, provided only it be stirred and shaken in such a way that many of its small parts may move, and move with them those of our hands."[1] Modern natural philosophers who have shown the exact relation subsisting between heat and mechanical motion, say nothing more precise as to the nature of heat. The theory which Descartes gives of light, without being conformable in all points with the present theory of undulations, is not only the antecedent of it, but the perfectly characterised germ. He often insists upon the idea that light is neither a body, nor a quality of a certain body, but "an action."[2] This action, of which the sensation of light is the result, he considers as "a trembling force which is doubled and relaxed with small successive shocks."[3] Making appeal to experience, he shows that motion

[1] "Le Monde," chap. ii. [2] "Principes," iii. 77.
[3] "Le Monde," chap. xiii.

alone suffices to excite in us the sensation of light: "If we receive a blow upon the eye, hard enough to affect the optic nerve, we seem to see a thousand sparks of fire, which, however, are not outside the eye," whence he infers the uselessness of "the real qualities and the substantial forms which the greater part of philosophers have supposed to be in the body."[1] From all these considerations together he concludes at last, in a general way, that "all the varieties there are in matter depend upon the motion of its parts." This is the title of the 23rd Article of the second part of the "Principes de la Philosophie." He developes his thought in these terms: "There is, therefore, but one and the same matter in all the universe, and we have knowledge of it by this fact alone, that it is spread through space; and all the properties that we perceive distinctly in it have relation to this alone, that it can be divided and moved according to its parts, and consequently that it can receive all the different arrangements which we observe can take place by the motion of its parts. For, though we may be able in our imagination to conceive divisions in this matter, nevertheless it is certain that our imagination has no power to change anything in it, and that all the diversity of forms which are met with in it depend upon local motion." In the last pages of his book he writes: "We do not perceive in any way, that all that is in objects which we call their light, their colours, their odours, their tastes, their sounds, their heat or cold, and their other qualities which are perceived by touch, and so what we call their substantial forms,

[1] "Principes," iv. 198.

are in them anything else than the various figures, situations, sizes, and motions, of their parts, which are so disposed that they can move our nerves in all the different ways which are requisite to excite in our souls all the different feelings which they do excite in them."[1]

Since all physical phenomena are motions, motion is universal; and where we do not perceive it, it is only because our senses are too feeble. "I consider," says Descartes, "that there is an infinity of diverse motions which are going on perpetually in the universe; and after having observed the greatest, which make the days, the months, and years, I take note that the vapours of the earth do not cease to rise towards the clouds, and to descend from them, that the air is for ever agitated by winds, that the sea is never at rest, that the fountains and rivers never cease to flow, that the most solid buildings fall at last to ruin, that plants and animals do nothing but grow and decay; in a word, that there is nothing in any place which is not changing; whence I know upon clear evidence that in all bodies there are a quantity of minute parts which do not cease to move, although because of their smallness they cannot be perceived by any of our senses."[2]

All material phenomena are reduced to motion alone; and it is the relation of the various motions with the soul capable of feeling, which constitutes the various properties of bodies: this is the fundamental principle of modern physics, not vaguely glimpsed, but dis-

[1] "Principes," iv. 198. [2] "Le Monde," chap. iii.

engaged from all clouds, and proclaimed as clearly and distinctly as possible. No other savant, to my knowledge, either before Descartes, or in the time of Descartes, has affirmed it so in all its generality, in all its precision, and in all its import and bearing.

Physiology does not fall within the compass of my essay; but still I cannot pass it altogether without notice. Descartes reduces physiology to physics; that is to say, according to his principle, to pure mechanics. He affirms that all that passes in the body of animals, and in that of man, is the result of the general laws which govern matter, provided we admit the creation of living bodies by God, a Worker of infinite wisdom, and the presence in the heart of organised beings of a special principle of motion analogous to heat. These two points admitted, all functions must receive a mechanical explanation. Just as there exist no substantial forms in physical phenomena, so in the life of animals there exists no principle of sensibility and intelligence. There are here two things to be distinguished: the negation of all psychical element in animals, and the explanation of the functions of organism, organism being once granted, by the laws of physics.

On the first point, Descartes has not been followed except by his own school. The protest of La Fontaine has generally been admitted, who sets forth admirably the Cartesian doctrine, and then concludes his story entitled, "The two Rats, the Fox, and the Egg," with these lines:—

"Qu'on m'aille soutenir, après un tel récit,
Que les bêtes n'ont point d'esprit!"[1]

The science of the present day is in agreement with the fabulist; the animals offer to our observation indisputable tokens of sensibility and intelligence. If Descartes has not been followed in his negation of a psychical element in animals, his idea of explaining physically organic functions has exercised a great influence upon the development of physiology, and is directing contemporary science in its researches.

All physics being reduced to mechanics, and all mechanics to the laws of motion, the laws of motion become the basis of the science of the material universe. These laws Descartes was the first to formulate. The first is that of the inertia of matter. "Each particle of matter continues always to be in one and the same condition, so long as its meeting with others does not constrain it to change it."[2] "If it is at rest, it does not begin to move of itself; but, when once it has begun to move, we have, in like manner, no reason to think that it will ever cease to move, with the same force, so long as it meets with nothing to retard or arrest its motion; so that if a body has once begun to move, we are to conclude that it thenceforward continues to move and never stops of itself."[3] By knowledge of this law "we are exempted from the trouble to which the learned are put when they would account for the fact that a stone continues to move for some time after it is out of the

[1] Livre x. fable 1:—

"Let them maintain, if they will, in face of such a fact as this,
That the brutes have no intelligence!"

[2] "Le Monde," chap. vii. [3] "Principes," ii. 37.

hand which has thrown it: for we ought rather to ask why it does not continue to move always."[1]

To this fundamental thesis, that bodies continue their motion so long as no foreign cause arrests them, is added the following: "Every body which moves tends to continue its motion in a straight line."[2] This affirmation is supported by the following consideration: "Of all motions, that in a straight line is the only one which is entirely simple, and the nature of which is understood in an instant: for, to conceive it, it suffices to think of a body as in the act of moving in a certain direction, which is the case in each one of the instants which can be determined during the time that it is moving; whereas to conceive of circular motion, or any other that can be, it is necessary to consider at least two of those instants, or rather two of its parts and the relation which exists between them."[3] Here we have in all its precision, and in all its substance, the law of inertia as it has been given in terms by Newton, Laplace, Poisson, and all the moderns. M. Carpenter, therefore, committed an historical error when he represented the law of inertia as having been divined by the genius of Newton.[4]

The communication of motion always takes place by impulsion and contact. Descartes' denying *à priori* the existence of a vacuum, as we shall see later on, could not admit any action of matter at a distance.

Matter, then, is inert. Its function is confined to

[1] "Le Monde," chap. vii.
[2] "Principes," ii. 39.
[3] "Le Monde," chap. vii.
[4] *Revue Scientifique* du 31 Aôut, 1872, page 199.

receiving and communicating motion. This is the first basis of mechanics; what follows is the second.

The action of the universal motive cause is a constant action. If motion ceases or diminishes, it is only in appearance; if it disappears in one form, it reappears in another. "It is impossible for motion ever to cease, or even to change, otherwise than as to the subject-matter of it; that is to say, the virtue or power of motion, which is met with in one body, may indeed pass in whole or in part into another body, and so be no longer in the first, but it cannot *not* be any longer in the universe."[1] There is therefore always in matter "an equal quantity of motion."[2] Hence it follows that, "when one body causes another to move, it loses as much motion as it gives to it." All that happens is, that to motions perceptible to us succeed others which are insensible, but which are none the less real. A stone, for instance, falls to the ground, and stops there. To all appearance, here is a motion which ceases; in reality, "the stone shakes the earth, and so transfers its motion to it; but this motion of the earth is insensible."[3] The things which we perceive are explained by those which we do not perceive, but which science forces us to suppose. The theory which reduces heat to a motion opens the door to the research for the equivalence of the apparent mechanical motion, and of that other motion which is heat. We must not admit that, in any case, the power of motion is lost. "If two bodies were exactly equal, and were moving with equal

[1] "Le Monde," chap. iii.

[2] "Principes," ii. 36.

[3] "Lettre à M——," Edition Cousin, tome x. page 129.

velocity towards one another, when they came to meet they would both rebound equally, and return each towards the quarter from which it came, without losing aught of their velocity."[1]

Descartes was the first to state the problem of the laws of the communication of motion in all its generality. From the consideration of these universal laws applied to matter—one in its fundamental properties—he rises to the conception of that relation of all things between themselves which constitutes the unity and harmony of the universe. Speaking of the "wanderings of the planets," which are always deviating more or less from their normal motion, he observes that "the particular motion of each body may be continually turned aside ever so little in as many different ways as there are other different bodies which are in motion in the universe."[2] We cannot fail here to recognise the theoretic basis of the researches, which, enlightened by the knowledge of Newton's law, have brought about the discovery of the planet Neptune by Le Verrier. D'Alembert, while ascribing to Descartes the glory of having been the first to think that there are laws according to which bodies communicate motion, adds: "This great man did not make so much as he might have made of so beautiful and fruitful an idea. He was mistaken as to the greater part of these laws."[3] His mistakes in this respect have often been pointed out, but it remains none the less an established fact that the general conception of science, as he expressed

[1] "Principes," ii. 46.
[2] "Principes," iii. 157.
[3] "Encyclopédie," Article PERCUSSION.

it, is the true conception; and that all subsequent researches have taken place in the direction which he had indicated. This is the characteristic of the work of a founder.

After having established the laws of motion, Descartes rises to the conception of a primitive state of matter, of which the actual organisation of the universe would be the consequence. This point of view, which is that of the ancient Greek atomists, had been revived by Gassendi; but, in the time of Descartes, the theory generally received was the immediate creation of the world as it is. Telesio, a bold innovator, who, in the sixteenth century, had founded at Naples an academy especially destined to combat the scientific sovereignty of Aristotle, had concerned himself with the *constitution* of bodies, but not with their *origin*, because he admitted, conformably to the common opinion, that "God formed them as we now see them."[1] Descartes therefore put forth a thought new to the general current of science, when he wrote, at the head of an article of his "Principes," this title: "How the sun and stars might have been formed."[2] It is in fact to him that we must attribute the first origin of the nebular theory. He declares that all that is in question is a simple supposition which may help to account for the constitution of things, and not an historical affirmation. He accepts, in fact, the theory generally received of the immediate creation of the world as it is. "If we consider," he says, "the omnipotence of God, we must conclude that all

[1] Bordas-Demoulin, "Le Cartésianisme," tome i. page 9.
[2] "Principes," iii. 54.

that He has made has had from the beginning all the perfection which it was to have."[1] Would this be an apparent concession, the result of the prudence of the author, and of his deference to received opinions? Readers of our own day will be inevitably led so to regard the matter. Those who have lived in familiar intercourse with Descartes, by the frequent reading of his works, will have no difficulty in admitting that it may be otherwise, and that he gave way in this case to a pious scruple, similar to that which induced him to maintain the automatism of dumb animals. As he did not allow of various degrees of spiritual existence, he feared lest, if he accorded to the brute anything of human nature, there might come savants who, starting with the idea that the brute has something of man, should conclude that man is only a superior animal. He might in the same way fear lest the theory of the gradual formation of the universe should lead minds of little depth to consider the successive character of that development as detracting in some degree from the Divine wisdom, or as being able even to replace it. M. Bouillier offers upon this subject the following judicious remarks: "Descartes bids us note, that if he supposes a gradual formation of the universe, it is the more clearly to explain its present condition; for he does not think that it consists with the greatness of God to create the universe by little and little, as if He had need to proportion to His powers the great task which He had undertaken; God had but to will, and at a single stroke the world was created. No doubt God could

[1] "Principes," iii. 45.

have created the world at a single stroke; but it does not seem to us to follow from His infinite perfection that He could not have created it in another way. Does a progressive development of the creation, conformably to immutable laws, witness less to the dignity and greatness of God than the entire universe created at a single stroke? To cause all the developments of the universe to proceed from a germ which virtually contains them all—is not this as great as to create all things simultaneously and at once, at their highest degree of perfection? Are we less to admire Him who created the egg, from which the bird will issue, than Him who at first created the bird?"[1]

Such is, in its principal features, the durable work of Descartes, in what concerns the science of nature. It is comprised in these three principal affirmations:—

The mechanical nature of physical phenomena.

The inertia of matter.

The conservation of energy.

These are the three foundations of modern physics.

To look for the mechanical explanation of natural phenomena by means of the double law of the inertia of matter and the constancy of force: this is the supreme rule of Cartesian physics, and it is the programme of all that contemporary science knows, and of all that it is seeking. On the day when this rule was laid down, the object of science was determined, and the guiding principle of thought was proclaimed. In what source had theories so novel and so bold their origin at the epoch when they were conceived? The

[1] "Histoire de la Philosophie Cartésienne," tome i. chap. 4.

answer to this question will be sought in the essay next following.

Descartes, when he had laid down the bases of physics as they exist in contemporary science, undertook the explanation of all the phenomena of astronomy and of physics. He believed, in particular, that he had accounted for the motions of the heavens by his celebrated system of vortices. It is not necessary to follow him in this road, in which he often went astray and fell into a number of errors; but it is important carefully to distinguish the foundations of science as he laid them, and the building which he raised upon these foundations. The importance of this distinction will come out very clearly as we pursue our researches.

THE WORK OF THE PREDECESSORS AND CONTEMPORARIES OF DESCARTES.

The mind of Descartes was very original and independent: the part which his own individuality had in his work is immense. To the accusations of plagiarism which were brought against him he replied, with legitimate pride, that he left it to his readers to decide if his thoughts were really his own. All attentive readers will admit at once the justice of the answer. Descartes, however, was the victim of an illusion, in imagining that he had been able to put aside all that he had learnt, and that his system proceeded wholly and entirely from his individual mind. He was not a plagiarist assuredly, but he drew, without being aware

of it, from the general current of human thought, as that current resulted from the antecedents of science, and from the work of his contemporaries.

Great historical facts preceded the epoch at which he wrote. The formation of national languages, the revival of the literature and philosophy of antiquity, the invention of printing, the discovery of America, the great religious commotions of the sixteenth century, the attacks directed against the physics of Aristotle at the same time as against his metaphysics, essays of independent philosophy—those of Bruno, for example, and Campanella;—all these facts had produced an immense disturbance in men's minds, and created a strong and influential love of novelty.

The desire of adventures, of which Daniel Defoe's "Robinson Crusoe" has been the most celebrated literary expression, made itself vividly felt in the domain of science, in which, as elsewhere, men were dreaming of the discovery of unknown lands. The intellectual hardihood of which the works of Descartes bear witness proceeded in great part, no doubt, from his personal character, but proceeded also from the general tendency of the minds of his epoch. Substantial forms had been attacked, when an edict of the Parliament of Louis XIII., bearing date 1624, forbade any person, *on pain of death*, "to hold or teach any maxim contrary to ancient and approved authors." A considerable movement had also been produced in the domain of the natural sciences, along with the struggle against the scholasticism and sovereignty of Aristotle, which movement had a character more especially philosophical.

Agricola, who died in 1555, had made a successful study of minerals and metals. William Gilbert, physician to Queen Elizabeth, who died in 1603, had laid the foundations of the theory of electricity and magnetism by labours which Liebig describes as "a long series of most admirable experiments."[1] Simon Stévin, physician to the Prince of Orange, and engineer of the dikes of Holland, who died in 1635, two years before the publication of the "Discours de la Méthode" of Descartes, had distinguished himself by mathematical and mechanical discoveries, and had obtained a glimpse of the fact, of capital importance, that air has weight. Lastly, astronomy, dating from Copernicus, had found a firm basis for the mathematical explanation of the phenomena of the heavens. Thus were preparing the elements of the science of nature; but with respect to a general theory of physical phenomena these were materials, and not the plan of the building. The stones were extracted from the side of the mountain, the wood for building was getting ready, but the architect was not come. This architect was not Bacon. The Lord Chancellor of England has often been pointed out as the real founder of modern science. He assigned to himself this character, with perfect sincerity, and many have believed him on his word; but history leads to another conclusion. Bacon is without doubt one of the great figures of the intellectual world. He has vindicated with more *éclat* than any one the rights of observation, the necessity of placing experiment at the basis of the mind's investigations; and he has in this way

[1] "Lord Bacon," par Justus de Liebig, page 83.

furnished important pages to the theory of the method, of which he has, however, failed to recognise the essential elements. He prophesied, with rare good luck, the development which arts and manufactures would take, by accurate knowledge of natural phenomena. But, as respects the general theory of physics, he did not apprehend the real direction of science, and one meets in his works with the traces of all the errors of the past. Beyond the study of physical causes, which serves for a basis to mechanics, which he considers an inferior science, he conceives of a theory of forms or essences which will make the high power of humanity, and the basis of processes which he describes by the term *natural magic.* These forms, which are to serve as a basis to natural magic, have a great resemblance to the substantial forms and virtues which figured in the scholastic philosophy. It happens to Bacon to content himself with occult causes admitted as principles of explanation. He puts the question: "Why does the salamander extinguish fire?" and he answers: "Because there is in the body of that animal an extinctive force which smothers the fire."[1] He does not divest matter of psychical attributes; and so he accepts for the formation of rock crystals the explanation given by an ancient naturalist,—Pliny, if I am not mistaken,—namely, that crystals are frozen water, which has remained so long in that condition that it has got the habit of it. So far is he from the doctrine of inertia, that he considers matter as being, after God, the cause

[1] "Vis extinctiva in corpore illius animalis quæ ignem suffocat," "Sylva Sylvarum," centurie ix. 860.

of causes (*causa causarum*). He attributes to it appetites. "It is evident that any man who should know the primitive passions, appetites, and processes of matter would by that alone have a general and compendious knowledge of facts past, present, and future, though such knowledge could not extend to particular and individual facts."[1] We might suppose that we were concerned here only with figures of language, if we did not meet with such explanations as the following: "The motion of *flight* is that by which bodies, by virtue of a certain antipathy, flee from or put to flight hostile substances, separate from them, and refuse to mix with them! . . . It is said that cinnamon and other fragrant substances, placed near localites which give forth foul smells, retain their odours the more obstinately, because they then refuse their emission and their mixture with fetid matter."[2] When bodies follow a straight line it is by a motion of haste. Bacon distinguishes nineteen sorts of motions, the last of which is the motion tending to inertia or abhorrence of motion. When we put bodies in motion, "they do not cease to labour to recover their rest, which is their natural state; that is to say, they strive with all their might to move no longer; and with regard to this last point, they do not fail in activity to obtain it: they tend to this end with sufficient nimbleness and rapidity, as though annoyed and out of patience with any delay."[3] Bacon was opposed to the acceptance of the theory of Copernicus. He qualifies as stupid the pre-

[1] "De la Sagesse des Anciens," xi.

[2] "Novum Organum," livre ii. § 48. [3] *Ibid.*

tension to seek in the motion alone of bodies the explanation of the phenomena (*motum corporum tantum stupide intuentes*).[1] Here is the direct negation of the foundation of modern physics. M. Liebig affirms that he remained in this respect so much behind his age that he denied the materiality of sound, of which he wished to make a certain *spiritual motion*.[2]

Bacon recalled science to its condition by proclaiming the necessity of experiment; but he entirely failed to recognise the object of science, and the direction to be given to its researchcs. He assuredly is not the principal founder of modern physics. The attacks of which he has been the object on the part of the Comte de Maistre and Liebig are impassioned, and in the main unjust by their violence, but they are true, so far as the point in question is merely the depriving Bacon of a usurped title. Two of Descartes' contemporaries, Kepler and Galileo, accomplished a work of a weightier character.

Kepler fills an eminent position in the history of the mathematics and astronomy. Leibnitz[3] accredits him with the knowledge of the inertia of matter. His labours certainly suppose the existence of that law, for the application of mathematics to the study of nature excludes all principle of spontaneity in bodies; but it is indubitable that the mind of Kepler oscillates between opposite conceptions, and that he has not affirmed inertia, as Descartes has done, with firmness and consistency. In the introduction to his work, "De Stella

[1] "Thema Cœli." [2] "Lord Bacon," page 85.

[3] "Réponses à Clarke," Cinquième Réponse, § 39.

Martis," he qualifies as animal faculty (*facultas animalis*) the principle of the reciprocal attraction of bodies. In the thirty-fourth chapter of the same work, he admits of a natural tendency in matter to rest, and to the privation of motion (*prona ad quietem seu ad privationem motus*), so that the planets would stop in their course by reason of their need of rest, but for a motive force incessantly renewed. We know, in short, that, now and then at least, he admits that the planets are governed by a soul acquainted with the road which it is to follow in order to maintain the order of the universe.[1]

To sum up, and without ignoring the great position of Kepler in the history of science, we may safely say that he did not, in a general and accurate way, lay the foundation of the theory of matter. This glory was reserved for another.

Was this other Galileo? Galileo enjoys a reputation as incontestable as it is uncontested. Astronomy recognises him as one of its most useful workers. His discovery of the laws of uniformly varied motion, and the observation of the pendulum, assure to him a place among the founders of modern mechanics. In short, he was the first to give, not only the practical example, but the theory of the true scientific method. In this last respect he is superior to Descartes. Of all the founders of modern science Galileo is the most judicious, the one in whose works there is the least to efface; but did he, as Descartes did, see and announce the bases of the true physics? Did he determine the

[1] Bertrand, "Les Fondateurs de l'Astronomie Moderne," page 150.

object of that science, the guiding principle of all its researches, and the end towards which it must tend? Did he affirm that all the objective part of phenomena is reduced to motion alone? Had he done so, he ought to be proclaimed the founder of modern physics, by the same right as Descartes; but he does not occupy precisely that position. He did not decidedly break with the theory of occult causes, for he introduces into his explanations the rather strange conception of a force attributed to the vacuum.[1] In his work entitled "The Assayer" ("Il Saggiatore") he does indeed express the opinion that the sensation of heat is the result of a mechanical action;[2] but he professes for the theory of heat and of light the doctrine of emission, that is to say, he admits specific properties of different forms of matter. I do not think, after having consulted on the subject a man very competent to judge, and who has made a special study of Galileo's writings, that he has anywhere made the general affirmation, that if we isolate physical phenomena from the impressions received by living beings, these phenomena are reduced to mechanics. A generalisation of this nature was little conformable to his genius, and to his manner of expressing his thoughts.

Galileo marches in the front rank in the study of the laws of mechanics; but did he completely admit and formally state the law of inertia? Newton in his "Principia," and Montucla in his "Histoire des Mathématiques," attribute to him the knowledge of this law.

1 "Galilée," par Th. Henri Martin, page 319.
2 Édition Alberi, tome iv. page 337.

M. Martin quotes in support of this affirmation a considerable number of passages.[1] From the examination of these passages it has seemed to me that Galileo disputes the doctrine which prevailed in his day, according to which the continuation of a motion produced by an accidental cause would be the effect of the medium which bends in behind the body and pushes it on before. For this way of explaining things he distinctly substitutes the idea of inertia, according to which the body continues indefinitely to move, and is only stopped by the resistances which it encounters; but it does not appear that he has affirmed the law of inertia in all its extent. In fact, in his "Système Cosmique," one of his latest writings, he declares himself of Aristotle's opinion, that there are two simple motions, the straight and the circular, and that the circular is perfect, and the straight imperfect.[2] This is the negation of one of the essential parts of the law of inertia, as Descartes established it, and as modern science has accepted it.

It is Descartes then who was really the first formally to state the general conception of the science of matter and the bases of the general theory of motion, as at this day we receive them. Bacon denies the fundamental principles of science. Kepler and Galileo suppose them and apply them in their works, but without conceiving them in all their purity, and without being invariably faithful to them. Descartes sees them disengaged from all cloud; he sees them and proclaims them. We are

[1] **Édition Alberi, i. 166 à 170 ; xi. 12 à 18 ; xiii. 159, 160, 221, 222.**

[2] **Bordas-Demoulin, "Le Cartésianisme," tome ii. page 48.**

not detracting at all from the legitimate honour due to his predecessors and contemporaries, nor seeking to veil the grave errors into which he fell; but, if it is allowed that the principal founder of modern physics is the man who first determined with precision the object of this science and the guiding principle of its researches, that man is Descartes; and we may say that the fundamental bases of modern physics date from the publication of his "Principes de la Philosophie," that is to say, from the year 1644.

Though his claim to priority of invention should be disputed, it would be impossible to question the preeminence of his influence in the establishment of the new ideas. Far and wide the world of science resounded with his praise, and the unanimous opinion of his contemporaries and his immediate successors justifies the affirmation of Laplace, that it is he who destroyed the empire of Aristotle, that is to say, the reign of the scholastic philosophy.[1] The capital point of the discussions of the period was the question of substantial forms; and nothing gives a better idea of the opinion of the seventeenth and eighteenth centuries on the destruction of this ancient doctrine, than a little amusing publication, entitled a "History of the Conspiracy made at Stockholm against M. Descartes."[2] This philosopher, summoned to Sweden by the Queen Christine, died of a pleurisy shortly after his arrival; and his death is thus accounted for in the writing in question:—

[1] "Exposition du Système du Monde," livre v. chap. 5.

[2] This little writing is found at the end of the "Voyage du Monde de Descartes," by the Père G. Daniel, new edition, Amsterdam, 1713.

"While M. Descartes was living quietly at the court of Sweden, whither he had been summoned by the Queen Christine in consequence of his excellence of character, his love of truth, his genius for the sciences, and the high reputation which he had acquired, there was formed against him one of the most dangerous conspiracies that, perhaps, were ever heard of.

"As he rejected from his philosophy several *Qualities* and *Accidents,* the existence of which it had entered no one's head to doubt of, *Heat* and *Dryness,* two of the chief Qualities, overcome with grief that he was making them to pass for chimerical *Beings,* resolved to avenge themselves for this affront, and to make this proud philosopher (so they called M. Descartes) feel their power. But before putting their design in execution, these Qualities thought fit to confer upon the subject with all those who, having been insulted by M. Descartes, were irritated against him.

"The *Substantial Forms* of every kind being of this number, as also the *Accidents,* with the *Virtues* and *occult Qualities, Heat* took care to propose to them a conference at which to deliberate upon the means of curbing the audacity of their enemy, and to take right measures in so important an affair. All promised to be present; and a day was appointed, and a convenient place chosen for this celebrated assembly. In this way, what was at the beginning only a conspiracy of a few *Qualities* became a general confederacy.

"So strong was the feeling against M. Descartes, that not one failed at the rendezvous. Still, as they had not been able to take up each one the position suited to

him, on account of the darkness of the place, there was at first great confusion; and several *Beings*, which have an antipathy for each other, having unfortunately met, began so furious a combat that it seemed likely to end only by the entire destruction of whichever should prove to be weakest. Already the *form of Fire*, the formidable enemy of the other forms, had brought several of them to bay. Already various *Accidents* were feeling the effects of its violence, and there was only the *form of Water* which had dared to oppose it. Unfortunately, everything had been strictly closed for fear that *Sound*, which is not very much given to secresy, might escape, and inform the first person it met of the result of the conference. But some one having opened the windows, *Light* got in, and by his pleasing aspect and brilliant effulgence delighted all the assembly, and brought into view all that was beautiful in the place. The combatants were separated, and each one was put into the place which suited him.

"All were not yet ranged in order when *Heat*, with great vehemence, represented to those assembled, That one knew no longer what to depend on since M. Descartes had published his 'Romance of Nature,' and had dared to strike out of the *categories* nearly all the *Beings* who were there present; that it was a shameful thing that, for so long a time, they had suffered that a new philosopher, despising all the sage Antiquity, should have the hardihood to treat as chimerical all that up to that time had been believed of their existence and functions; that as soon as possible they must punish this daring innovator who had sworn to compass their ruin, and make him

feel not only that they existed, but that they had the power to cause himself to perish. . . .

"The *occult Qualities* rose in their turn, and complained that this new philosophy took from them their principal privilege, which consisted in being unknown to the savants. They said that they had always had peaceful enjoyment of this privilege, and that great men had not ventured to examine the secret springs by which they had brought to pass so many marvels. That, on the contrary, they had confessed their ignorance on this subject; that, nevertheless, M. Descartes, more hardy, or, rather, less wise, than his masters, pretended to have discovered what had been so long concealed, and wished to make common and easy to be understood all that was most surprising in the actions of *occult Qualities*, which was nothing more nor less than to deprive them of the admiration which was their due.

"As each one had reasons for favouring the *occult Qualities*, their complaint was considered a just one. But that which *Light* made was judged still more reasonable. 'Who would ever have thought,' said she, 'that a philosopher would dare to make an attack on me, and deny my existence? Can any one open his eyes, and not acknowledge that I exist? And is it not astonishing that there are men ungrateful enough to labour to destroy me, at the very time that they are enjoying my benefits?' . . .

"The *Colours*, those amiable daughters of *Light*, who borrow from their brilliant mother all that they possess of splendour and beauty, joined their complaints to

pressed, he confessed that he was well aware that the great reputation of M. Descartes had dazzled him: that he had never properly considered the injury which he had received from that philosopher: that he understood at last the consequences of his doctrine; and that he did not pretend either to maintain it in public, or to approve it in private. Then M. Descartes having no longer a defender, his ruin appeared to be assured: and the votes having been collected, this unfortunate philosopher was declared an innovator and leader of a sect; a rebel against the laws of the ancient and true philosophy; disturber of the order of the categories; enemy of the *Virtues* and *occult Faculties;* of the *Accidents absolute* and *non-absolute;* of the *first* and *second Qualities;* of the *Forms,* the *Elements,* and *mixed Bodies;* of *material Souls, vegetative* or *sensitive;* of the *Instincts, incomplete Substances,* and generally of all the *Forms* as well *substantial* as *accidental:* and as such, condemned to undergo the penalty which the assembly should see fit to impose upon him.

"This judgment having been solemnly pronounced, all that remained was to choose the kind of punishment which the criminal must suffer. The *Forms* of the most ferocious Beasts of the country offered at once to tear M. Descartes in pieces, and to go and do it in the very palace of the Queen. But, as the matter would so become too public, and the enterprise might be fatal to the conspirators, they rejected this proposal, and resolved to avenge themselves in so secret a way that no one should be able to bring a charge against them.

"Upon this, *Sound* said: That if *Light* would act in concert with him, it would be easy to prevent the pretended philosopher from being either seen or heard; and that they would hinder the man himself from seeing and hearing.

"But *Heat* was not of this opinion: and in her impatience to gratify her hatred and vengeance, If you will allow me to do it, said she to the conspirators, I will operate in the body of M. Descartes with such violence, and I will put such disorder into his humours by the conflict which I will raise between the contrary *Qualities*, that in a short time I will set you free from this formidable enemy.

"This was approved of by the whole assembly; and it was decreed that the proposal should be acted upon. *Heat* was requested to put this design into execution as soon as possible. After which each one left according to his rank, and with much order, so as to avoid fresh occasions of dispute.

"*Heat* was only too expeditious. It was known soon after that M. Descartes had been seized with violent fever, attended with delirium; and a few days afterwards it was understood that he was dead, and that all the knowledge which he believed he had acquired had not availed to prolong his life."

We see that the destruction of substantial forms which, from the negative point of view, is the foundation of modern physics, is here attributed entirely to Descartes. The preponderant position which he held in the great movement of thought at this period is, moreover, established by a number of important facts.

Thirteen years after the philosopher's death, his works were condemned by the Congregation of the Index *donec corrigantur.* This decision of the Roman congregation was, in France, the signal for a desperate war upon the new doctrines. The University solicited a decree of the Parliament against the teaching of the Cartesian theories. The first president, Lamoignon, told Boileau that the Parliament would be obliged to grant the decree which was demanded of it. Boileau, with the assistance of Racine and Bernier, drew up a burlesque decree in favour of the maintenance of the doctrine of Aristotle. In this document the Faculty of Medicine, which was opposed to the introduction of cinchona and other remedies unknown to Aristotle and Hippocrates, is treated with small consideration. In what concerns our object, the decree is to this effect: "That an obscure person named Reason had attempted to enter by force into the schools of the University . . . had attempted to defame and to banish from the schools of philosophy the formalities, materialities, entities, virtualities, ecceïties, petreïties, polycarpeïties, and other imaginary beings, all children and lawful heirs of Master Jean Scot, deceased, their father; that this would produce serious injury, and lead to the total subversion of the scholastic philosophy, of which they make all the mystery, and which draws from them all its subsistence, unless it were by the court provided against. . . . The court, having regard to the said request, has maintained and kept, maintains and keeps, the said Aristotle in the full and peaceable possession and enjoyment of the said schools; . . . reinstates the

entities, identities, virtualities, ecceïties, and other like Scotist formulæ in their good fame and renown; . . . enjoins on all regents, masters of arts, and professors, to teach as they have been accustomed to do." Such, in the burlesque decree, is the measure dealt, along with physicians and other savants, "to certain facetious persons," amongst whom are reckoned the Cartesians. Here is seen manifested, as in the Stockholm conspiracy, the general state of opinion; the accurate perception that the question of substantial forms was the capital question in the scientific discussions of the time, and the recognition as matter of history no less accurate, that Descartes was one of the principal authors of the scientific revolution which had excluded them. The burlesque decree produced its effect, and Lamoignon was thankful to Boileau for having, by making him laugh, prevented him from allowing a decree to be granted which would have made others laugh.[1] Parliament therefore kept silence; but, in default of an Act of Parliament, an edict of the king expressly forbade the Cartesians to teach in France. The professors attached to the new doctrine had only a choice between retractation and exile. Cartesianism had a strong hold in the congregation of the Oratoire, which had produced Malebranche, and which was obliged to succumb to the influence of the Jesuits, become the principal adversaries of the new doctrine. In 1678 a general assembly of this congregation had to

[1] See for this fact, and for the persecution of Cartesianism in general, Bouiller, "Histoire de la Philosophie Cartésienne," tome i. chap. xxii.

accept a concordat with the Jesuits, in which we read: "In physics there must be no departure from the physics nor from the principles of the physics of Aristotle, commonly received in colleges, in favour of the new doctrine of Monsieur Descartes, whom the king for good reasons has forbidden to teach. The teaching to be given is: That in every natural body there is a substantial form really distinct from matter; that there are real and absolute accidents inherent in their subjects."[1] Here is the maintenance of the ancient physics by the authority of a royal edict; and we see that the new doctrine is attributed entirely to Descartes.

After a time of persecution the triumph of Cartesianism was complete. The foundations of modern physics were laid; there remained a two-fold work to accomplish: to correct the errors of the founder, and to develop the consequences of the truths which he had discovered.

The Errors of Descartes.

One of Descartes' important errors has reference to the conception of matter. He had reduced the idea of it to the occupation of a determined part of space. The fact of occupying a determined part of space, and consequently of resisting other bodies which might tend to penetrate into the same place, is the manifestation of a force. Of this force Descartes cannot help

[1] "Recueil de Quelques Pièces Curieuses concernant la Philosophie de M. Descartes," Amsterdam, 1684, pages 11 et 12.

taking account. "A body," says he, "always occupies a part of space in suchwise proportioned to its size, that it could not fill a larger, nor contract itself to a smaller, nor, so long as it remains there, allow any other body to find place in it."[1] Here we find, together with the affirmation of the absolute fixity of the space occupied by the elements of matter, the necessary idea of their force of resistance. But this idea of resistance in space, which is the true motion of a body, Descartes forgets, in consequence of his exclusive pre-occupation with mathematical conceptions; he identifies body with the geometrical conception of figurate extent. In his system, body is identical with extent, and contains nothing more, so that a vacuum is impossible and inconceivable. So, to the question: What would happen if all the matter which is in a vessel were withdrawn from it without any other penetrating into it? he answers without hesitation, "The sides of the vessel would touch one another."[2] Marguerite Perrier used to say: "The late M. Pascal, when he wished to give an example of an illusion[3] which might be defended by an obstinate reasoner,[4] used generally to instance the opinion of Descartes respecting matter and space."[5] This false theory introduced a certain number of errors directly into the physics of Descartes. Thus it is, for instance, that from the negation of a vacuum combined with the idea of the absolute fixity of the space occupied by bodies, he infers that the transmission of

[1] "Le Monde," chap. vi. [2] "Principes," ii. 18.
[3] *Une rêverie.* [4] *Par entêtement.*
[5] "Pensées de Pascal," Édition Faugère, tome i. page 369.

light is instantaneous. What has graver consequences, is that the purely geometrical conception of matter leads him to cross the line of demarcation which separates physics from mathematics. He persuades himself that the first of these sciences can be constructed, as the second, by a purely deductive process, namely, by applying to a certain number of ideas *à priori* the laws of the understanding. Hence it follows, that instead of considering the foundations which he had laid as guiding principles in hypotheses constantly submitted to the control of experience, he takes them as the basis of immediate deductions. He believes therefore that he is in a position to construct a system without recourse to the slow road of experience, and he makes, at the end of his "Principes de la Philosophie," this lofty declaration: "That there is no phenomenon in nature which is not comprised in what has been explained in this treatise."[1] He had pointed out the end of science, and he believes that he has attained it. This conception of method is the principal source of his errors, and his errors are numerous.

There was much therefore to retouch in his doctrine taken altogether, and this was the business of his successors. Huyghens states precisely the theory of luminous waves. Leibnitz establishes the difference between the quantity of motion expressed by mv, which varies, and *live force*, expressed by mv^2, which is constant; and he treats this subject in pages, in reading which one is sensible of some impatience on the part of the writer caused by the servility with which the Car-

[1] "Principes," iv. 199.

tesians followed, even in his errors, the bold innovator whom they had chosen as master.[1] Leibnitz, therefore, corrects Descartes' statement, who had affirmed the conservation of an equal quantity of motion; but he corrects it without modifying his fundamental affirmation; for the fundamental affirmation of Descartes was the constancy of universal motive action; and the conservation of the equal quantity of motion was a deduction which, according to his vicious method, he did not submit to the control of experience. Leibnitz again corrects the master, to whose influence in many respects he was subject, on a point more fundamental. He rectifies the conception of matter identified with figurate extent, in order to re-establish the indispensable notion of the force by virtue of which a body offers resistance.[2] Monads, which, in the domain of physics with which alone I am here concerned, are centres of forces, express a notion which Descartes had committed the error of denying, although, as we have seen, he was forced in all his explanations to suppose it. To restore this notion was to open to the theory of atoms, understood in its most general sense, a door which Cartesianism kept closed.

Newton, from a less speculative standpoint than Leibnitz, points out as he does the force of resistance of matter: *Materiæ vis insita est potentia resistendi.*[3]

1 "Brevis Demonstratio Erroris Memorabilis Cartesii," Œuvres de Leibnitz, Édition Dutens, tome iii. page 180.

2 "Lettre sur la Question si l'Essence du Corps consiste dans l'Étendue," insérée dans le *Journal des Savants*, Juin, 1691, Édition Dutens, tome ii. partie 1, p. 234.

3 "Principes," Definition iii.

Taking as his basis the observations of Tycho-Brahe and the laws discovered by Kepler, he establishes the true system of the motions of the heavens by formulating the law of gravitation. Thus he corrects the errors contained in the system of vortices. Finally, following the road opened by Galileo, and adopting the sound portion of the ideas of Bacon, he draws up, in opposition to the attempts at explanations, *à priori*, the rules of the true method, and puts them in practice. The corrections of Cartesianism effected by Newton are, therefore, very important; but it is easy to discover that, as to the fundamental conception of his work, the principle, namely, of the explanation of phenomena, he follows in the steps of Descartes. "Descartes," said Laplace, "was the first who endeavoured to reduce the motions of the heavenly bodies to mechanics." [1] Newton himself writes as follows at the beginning of the preface to his "Principia":—"The ancients, as Pappus informs us, attached great importance to mechanics in the interpretation of nature, and the moderns have at last, for some time past, rejected substantial forms and occult qualities, and brought natural phenomena under mathematical laws. Our purpose in this treatise has been to contribute to this object, by cultivating the mathematics in what relates to natural philosophy. Newton has been reproached for having omitted in this passage the name of Descartes, who was without question the principal author of the scientific revolution which had rejected substantial forms and occult qualities in order to bring in

[1] "Exposition du Système du Monde," livre ii. chap. 5.

mechanical considerations to the explanation of natural phenomena.

Newton, following Descartes as to the mode of explanation of phenomena, corrects the faults of construction of that philosopher in what concerns astronomy. Other savants correct his errors in mechanics and special physics. The catalogue of these necessary corrections would be long; but this does not alter the fact that Descartes, more than any one else, fixed the object of physical researches, and the direction of the science. When gold-ore has been extracted from the bowels of the earth, it is often necessary to purify it, but this labour of refining it does not detract from the merit of the man who obtained the gold from the mine. M. Joseph Bertrand remarks, especially with reference to mechanics, that Descartes put forth inaccurate assertions; but he adds: "With these false assertions are mingled great and pregnant truths which at this day are governing science."[1] To discover the ideas which govern science is the proper mark of founders. M. Bertrand says again: "Time, we may be sure, sets great and novel ideas free from the imperfections which are associated with them."[2] Minds of the second order, giving themselves to the labour of reflection and experiment, suffice to correct the errors of a doctrine; but to disparage the work of an inventive genius because he has not immediately advanced science to the point to which his successors have succeeded in conducting it, by following up an impulse which proceeded from him, would be a manifest injustice.

[1] *Journal des Savants*, Juin, 1874, page 413.

[2] *Ibid.* page 418.

Development of the Cartesian Physics.

At the same time that the progress of science was rectifying the errors of Descartes, it was developing the truths which he had discovered. This development may be divided into two periods. In the first, it is the mechanics of large bodies, and especially astronomy, which goes on improving. Passing by Leibnitz, Newton, and the series of great geometricians of the eighteenth century, we come to Laplace, who expressly acknowledges that his work is the topstone of a building of which Descartes laid the foundation. Kepler and Galileo, although they did not affirm with absolute distinctness the mechanism of phenomena, and the law of inertia in all its generality, have at the beginning of this period, and with especial regard to astronomy, an importance equal to that of Descartes.

The second period is characterised by the endeavour made to bring under the laws of mechanism, and the unity of matter, all physical and chemical phenomena, the motion of the molecules of ponderable bodies, and those of ether. This is especially and almost exclusively Cartesian. Boyle had laboured in this direction. Leibnitz praises him for that "his capital point was to inculcate that everything in physics takes place mechanically;" then he adds: "It is the misfortune of men to be disgusted at last with reason itself, and to get tired of the light."[1] In fact, the direction impressed upon researches by Boyle was not immediately followed. It

[1] "Réponses à Clarke," Cinquième Réponse, § 114.

is only right to observe, in order to assign its proper value to the censure passed by Leibnitz, that at that time there were wanting two of the conditions necessary to the fulfilment of the Cartesian programme. One of these conditions was a sufficient number of observations in physics, and the extension which the data of experimental chemistry were to take under the impetus received from Lavoisier. The other was the infinitesimal calculus, if it is true, as Biot says,[1] that "almost all questions of physics are accessible, so to speak, only by considerations drawn from the infinitely small." It is in the first part of the nineteenth century that the second period of the development of the Cartesian physics really begins; then it is that one begins to see and is able, with some confidence, to proclaim the possibility of reducing the whole system of physics to mechanics. This movement is far from its term, as I have shown in my first Essay. The danger at this day is that of falling back into the illusion of Descartes, and of thinking one has found that which must still be sought for. Laplace, whose work is the crowning point of the first Cartesian period, has described in the following terms, at the beginning of his "Essai sur les Probabilités," the end and purpose of the labours of the second period. "An intelligence which, for a given moment, should know all the forces with which nature is animated, and the respective situation of the beings which compose it, if moreover it were vast enough to submit these data to analysis, would embrace in the same formula the motions of the largest bodies

[1] Article "Leibnitz," dans la "Biographie Universelle."

of the universe and those of the lightest atom: nothing would be uncertain for it, and the future, as the past, would be present to its observation. The human mind presents, in the perfection which it has been able to give to astronomy, a faint outline of such intelligence." Laplace deals with the same subject in his "Exposition du Système du Monde."[1] "When we see all the parts of matter subjected to the action of attractive forces, one of which extends indefinitely into space, while the others cease to be perceptible at the smallest distances of which our senses can take account, we may wonder whether these last forces are not the first modified by the shapes and mutual distances of the molecules of bodies. . . . The affinities would then depend upon the form of the integral molecules and their respective positions; and it would be possible, by the variety of these forms, to explain all the varieties of attractive forces, and so bring under one sole general law all the phenomena of physics and astronomy. But the impossibility of knowing the shapes of molecules and their mutual distances, renders these explanations vague and useless for the advancement of the sciences."

Since the epoch when Laplace wrote this, we possess, or we see our way to, explanations less vague, and more likely to promote the advancement of the sciences. Still, M. Helmholtz spoke as follows to the congress of German naturalists at Inspruck, in 1869: "All, in external nature, is reduced to a change of form in the aggregate of the chemical elements eternally invariable, to differences of composition, of distribution, of struc-

[1] Livre iv. chap. xviii.

ture, in the bodies which those elements constitute. In whatever manner they present themselves, they remain essentially the same. In other words, there is no change possible in nature, except the different distribution and arrangement of the elements in space, and this is tantamount to a *motion.* And it follows that if all changes are motions, the forces which produce these changes can only be mechanical forces. But this result of chemistry has been but slowly brought about; and we are far from having really reduced all natural actions to a primitive action of motion. . . . The variety and manifold complication of these actions, the impossibility of directly observing them, are so many obstacles which prevent our arriving at the first form of motion. This is a work the realisation of which is reserved for a yet distant future, and which the present generation perhaps will not see."[1] M. Marignac expressed himself to the same effect, in 1879. Speaking of the affinity and disengagements of heat which accompany the combinations, he observed that there are many questions "the solution of which as yet escapes us entirely."[2]

We are marching with a firm and sometimes rapid step towards the mark pointed out by Descartes. Everything leads us to hope that contemporary science is on the right road; but it is well to advance with caution and prudence at a time when the systematic spirit is awakening with extreme energy, and when

[1] *Revue des Cours Scientifique*, du 8 Janvier, 1870.

[2] *Archives des Sciences Physiques et Naturelles*, de Décembre, 1879, page 676.

thinkers more bold than prudent are sometimes talking as if we had already accomplished the work of which M. Helmholtz has the wisdom to reserve the completion to future generations.

The fundamental principles of science accepted by our contemporaries being those which Descartes laid down, how comes it that the discovery of these principles is so often supposed to date from the present century? An historical fact will supply the answer to this question.

Obscuration of the General Theories of Physics.

Between the two periods of the development of the Cartesian physics, and while science was making considerable progress in the analysis of phenomena and in the establishment of experimental laws, there took place an obscuration in the fundamental idea of the theory of matter. This eclipse lasted for about a century—from the year 1720, when Privat de Molière was still receiving the applause of the auditors of the College of France as he defended the bases of the Cartesian doctrine, till the year 1820, when D'Oersted's discovery of the relations between electricity and magnetism, following upon the labours of Fresnel on the nature of light, brought men's minds to the conception of a unique fluid, the different motions of which produce the variety of the phenomena. This recoil of thought in the general theory of nature is accounted for by two causes which are intimately connected: the errors of Descartes, and a mistake of the learned world.

The corrections applied by Leibnitz to the Cartesian theories did not affect the bases of those theories except to strengthen them by rectifying the statement of them. The action exercised by Newton had another character. Newton opposed to the false explanations of the system of vortices the true explanation of the motions of the heavenly bodies by the law of gravitation. To the *à priori* method he opposed the true processes of experimental science. It was upon the occasion of these corrected errors that there took rise in most minds an enormous misconception. Newton had discovered the law of astronomical phenomena; but, in establishing the law of gravitation, he had not pretended to indicate the cause of it, and he suspected that that cause might be found in the action of an ethereal fluid enveloping ponderable matter, a conception which in substance was that of Descartes.[1] The followers of Newton did not understand him, notwithstanding all the precautions which he had taken in order to be understood, and, unfaithful to the thought of their master, they wondered that attraction was a force inherent in matter, and that in virtue of that force bodies acted one upon another across the vacuum,—an idea which Newton had formally repudiated.[2] There was opposed, therefore, not the law of Newton to some of the affirmations of Descartes, which was right, but gravitation, conceived of as a first cause of the phenomena, to the doctrine of the action of the universal fluid upon ponderable bodies,—an opposition which had no ground whatever. The latest Cartesians, Privat

[1] "Optique," question xxi.

[2] "Lettre au Docteur Bentley."

de Molière, Fontenelle, Mairan, made vain efforts to show that the mathematical law of the motions of the stars was a truth of another order from the theories relating to the physical causes of those motions, and that, the law being admitted, the investigation of the causes might continue in the direction indicated by Descartes.[1] All was confounded which should have been distinguished: the establishment of the laws, and the theory of the causes; Descartes' errors of detail, and the essential ideas of which errors of detail did not establish the falsity; the defect of the *à priori* method, and the determination of the object of science which was to furnish the guiding principle of hypotheses. There were good reasons for rejecting in great part the *construction* of Descartes, and they rejected without reason the *foundations*, which the faults of construction did not invalidate. The general theory of matter underwent an obscuration. If it is allowed that the modern system of physics is true, we must say, without hesitation, that at that time truth retrograded.

The followers of Newton sheltered under the name of their master errors which he had rejected. The master had taken even an excess of precautions, as I have just said, in order that there might not be attributed to him the idea of the action of bodies at a distance, and the notion that weight is an essential property of matter. Nevertheless, even in 1713, and in the preface to an edition of Newton's "Principia," Côte affirms that weight is a primitive property of

[1] Bouiller, "Histoire de la Philosophie Cartésienne," tome ii. chap. xxiv.

bodies, as well as their extent and their mobility.[1] This affirmation is not tenable. It is possible that gravitation may remain for science a first principle, beyond which it may not be able to ascend; but without extent and mobility a body becomes inconceivable for us, which is not the case as to weight. The inherence of weight, instead of remaining a debatable theory, became, in the new school, an uncontested affirmation, and almost a common-place.

Newton supposes the existence of a subtile, ethereal medium, which he calls ether, as we call it at this day. "This medium," says he, "is it not infinitely more rare and more subtile than air, and exceedingly more elastic and more active? Does it not easily penetrate all bodies? and is it not, by its elastic force, diffused through all the heavens?"[2] Côte would banish from the universe "this subtile matter which owes its existence to the imagination, and would send it back into the nothingness from which it had been drawn forth."[3] The School follows Côte's opinion, and "it is one of the principal dogmas of the Newtonian philosophy" (in direct contradiction to Newton's idea) "that the immensity of the universe contains no matter whatever in the spaces which lie between the heavenly bodies."[4] What is the opinion upon this subject at the present day? The existence of ether is at the basis of all the theories of contemporary physics, and M. Lamé, at the

1 "Principes de Newton," traduction francaise. Préface de M. Côte, page 29.

2 "Optique," question xviii.

3 Préface aux "Principes de Newton," page 34.

4 Euler, "Lettres à une Princesse d'Allemagne," partie i. lettre 18.

end of his "Leçons sur l'Élasticité," declares that "the existence of the ethereal fluid is incontestably demonstrated." If, therefore, modern science has not mistaken its road, the followers of Newton were wrong in their polemics against the Cartesians on the subject of the ethereal fluid. In this the disciples contradicted their master; but there are three errors which remain chargeable upon that great man.

The first of these errors is the idea that force is lost. Newton asks, if we exclude the idea of such a disposition of matter as causes it to fly back, what will happen "if two equal bodies, moving directly towards one another with equal velocities, meet in a vacuum." He answers: "They will stop at the place at which they meet, will lose all their motion, and remain at rest."[1] Descartes, proposing to himself the same problem, had solved it in a directly opposite way: "If two bodies were exactly equal, and were moving with equal velocity in a straight line towards one another, when they came to meet they would both rebound equally, and would return each towards the quarter from which it had come, without losing any of their velocity."[2] To understand the problem, which is purely theoretical, we must suppose two primitive elements of matter, two atoms, which prevents us from looking for the equivalent of the motion of translation in an internal molecular motion. If the problem stated in these terms is accepted, we must renounce the principle of the conservation of energy, or admit that Descartes was right, and that it was Newton who was mistaken. The two

[1] "Optique," question xxxi. [2] "Principes," ii. 46.

opposite opinions came direcly into conflict. In 1715 Clarke maintained against Leibnitz the opinion that two bodies destitute of elasticity, meeting with contrary and equal forces, lose their motion. The answer of Leibnitz is as follows:—"It is maintained that two soft or non-elastic bodies, meeting one another, lose their forces. I reply that this is not the case. It is true that the wholes lose force in respect of their total motion; but the parts receive it, being agitated internally, by the force of the concussion. Thus this loss only takes place in appearance. The forces are not destroyed, but dissipated among the small parts. This is not to lose them, but to do as those who change large money into small. I acknowledge, however, that the quantity of motion does not remain the same; but I have shown elsewhere that there is a difference between the quantity of motion and the quantity of force."[1] The comparison of large money changed into small is ingenious, and a professor of physics would not say better now-a-days. The correction of the system of Descartes, to which Leibnitz makes allusion, is the substitution of the formula of live forces $m v^2$ for that of the quantity of motion $m v$. The followers of Newton did not give in; and the following is an instructive page in the history of science,—in which Maclaurin, giving account of the discoveries of Newton, condemns, as was common at the end of the eighteenth century, the essential basis of modern theories, namely, the conservation of energy, and the equivalence of the motions of ether to mechanical motions.

[1] "Réponses à Clarke," Cinquième Réponse, § 38.

"Descartes maintained that the quantity of motion in the universe was always the same. M. Leibnitz made a distinction between the quantity of motion and the force of bodies. He confesses that the first varies, but maintains that the quantity of force is always the same in the universe. There is, however, no doctrine more opposed to experience and to the commonest observations, even though the force of bodies should be measured by the squares of the velocities, as he pretends to do. If all bodies in the world had a perfect elasticity, this principle might be maintained with some show of reason. But no body has as yet been discovered the elasticity of which is perfect; and when two bodies meet with equal motion, they rebound with slower motions, and there is always some force lost by the shock. If the bodies are soft, they both stop by reason of the impenetrability of their parts; or, to speak in the favourite style of this author, because there is no sufficient reason why one of them should prevail rather than the other. In this case all their motion is lost; and the motion of the one being destroyed by the opposite motion of the other, it is without ground, and merely to defend an hypothesis, that the existence of a fluid is imagined which receives and retains the force of these bodies."[1]

The second affirmation of Newton—which must be considered as an error, if we allow that contemporary science is right—is that the motion of the planets offers certain irregularities, which will go on increasing,

[1] Maclaurin, "Exposition des Découvertes Philosophiques de M. le Chevalier Newton," livre i. chap. iv. page 88.

until the system of the universe has need to be readjusted by a special intervention of creative power.[1] Leibnitz refutes this opinion by arguments altogether Cartesian.

"M. Newton," he says, "believes that the force of the universe goes on decreasing, like that of a watch, and requires to be re-established by a particular action of God; whereas, I maintain that God made things at first so that force should not be lost."[2] Maclaurin taunts him sharply enough with holding this opinion.[3] We, however, consider the theory of the stability of the universe, due to the labours of Laplace, as one of the conquests of modern astronomy. Laplace, in truth, does not say but that the actual organisation of the universe may be destroyed by natural causes,[4] and he so opens the door to the recent hypothesis of M. Clausius upon the consequences of the laws of heat; but the question agitated in Maclaurin's time was that of a disturbance of our system resulting from the mutual attraction of the stars; and upon this point the calculations of celestial mechanics have proved Leibnitz to have been in the right.

The third error of Newton is that of having denied the doctrine of luminous undulations established by Huyghens in the direction of the idea of Descartes, and of having adopted the theory of emission, which was that of Galileo. "Are not the rays of light," he says, "very small corpuscles shot forth or propelled from

[1] "Optique," question xxxi. vers la fin.
[2] "Lettre à M. Bourguet," édition Dutens, tome ii. page 335.
[3] "Exposition des Découvertes de Newton," livre i. chap. iv. page 87.
[4] "Exposition du Système du Monde," à la fin.

luminous bodies?"[1] It is to be remarked that the affirmations of the master upon this subject are less explicit than those of his disciples; and Newton perhaps adopted the theory of emission less as the expression of the reality than as an hypothesis which afforded facilities for calculation. However it were, it is beyond dispute that the negation of the theory of undulations was placed under the authority of his name, and this negation besides was necessarily imposed upon the school which affirmed the absolute vacuum of the spaces lying between the heavenly bodies. This doctrine, which made of light a special agent and a substantial reality, possessed great importance. The savants were led thereby to the idea of specific properties of various species of bodies—properties indeterminable otherwise than by the effects which they produce upon beings capable of sensation. This was to renounce mechanical explanations, and was, in fact, a return to the ancient physics; for these specific indeterminable properties have a great look of the substantial forms and occult causes.

At the same time that Newton's errors were modifying in a way to be regretted the direction of researches, some followers of Leibnitz were deducing from the metaphysics of their master the negation of the law of inertia, by attributing to matter a tendency "to be continually changing its proper condition."[2] A double smoke was thus issuing from two great centres of light.

[1] "Optique," question xxix.

[2] Euler, "Lettres à une Princesse d'Allemagne," partie ii. lettres 5 et 8.

We may affirm, therefore, that at the end of the eighteenth century, while the mathematical development of the truths discovered by Kepler, Galileo, and Newton was making considerable progress, and while the experimental part of science was being enriched unceasingly, chiefly by the scientific organisation of chemistry, the fundamental conceptions of physics were obscured. The triumph of Newton's followers was complete; and the assurance with which they affirmed that they alone were right, upon points in which at the present day we judge them to have been in error, may serve to make us prudent in the employment we are often making of *modern science* as of an indisputable authority.

The mechanical explanation of natural phenomena was maintained in the eighteenth century in the materialistic school. In the "Système de la Nature" of Baron d'Holbach it is said: "The universe—that vast assemblage of all that exists—presents to us everywhere only matter and motion."[1] But in this theory the essential basis of the labours of Descartes is ignored — the distinction, namely, between corporeal and spiritual phenomena.[2] We must, therefore, either maintain the untenable paradox that psychical facts are nothing but motions, or attribute to matter a power of producing something else than itself, which is contrary to the doctrine of inertia. The revival pure and simple of the ideas of Democritus and Epicurus was not

[1] Partie i. chap. 1.

[2] This distinction has been pointed out by M. Du Bois-Reymond with a lucidity worthy of a disciple of Descartes. See the *Revue Scientifique* du 10 Octobre, 1874.

the natural and legitimate outcome of the grand theories of the seventeenth century.

In the period of the recoil of the fundamental conception of physics, we find some men maintaining the Cartesian tradition. Daniel Bernouilli developes the theory of the constancy of force; Euler defends the hypothesis of ether and the theory of undulations, and resists the return of occult causes reappearing under the form of specific properties inherent in matter."[1]

But these were only exceptions. In the system of physics generally admitted at the beginning of this century, the principle of the conservation of energy had been forgotten; various phenomena were attributed to distinct agents; it was not sought to establish direct relations between physical actions and chemical affinities. Of the fundamental principles established in the time of Descartes, the law of inertia alone had remained unassailed by any disputation; and this it owed above all to the acknowledged solidity of the astronomical system. For now about sixty years past, things have altered their position.

Revival of the Cartesian Physics.

In 1818, Fresnel re-establishes the theory of luminous undulations. The discoveries of D'Oersted in the relations between electricity and magnetism, discoveries rendered fruitful by the genius of Ampère, date from 1820. In 1828, Auguste de la Rive determines the chemical antecedents of the production of voltaic

[1] "Lettres à une Princesse d'Allemagne," partie i. lettre 68.

electricity. In 1842, Robert Mayer, and, nearly at the same time, Joule and other savants, propound the mechanical theory of heat. These grand scientific innovations are not without precedents. In 1798, Rumford had originated the idea that heat was only a motion, and had confirmed it by some experiments. We read in the work of M. Séguin, entitled "De l'Influence des Chemins de Fer": "Montgolfier communicated to me, when I was still very young, the deliberate opinion which he had formed, that there exists a real identity between caloric and the mechanical power which it serves to develop, and that the two effects are only the apparent manifestation to our senses of one and the same phenomenon."[1] Joseph Montgolfier died in 1810, so that the communication of his ideas to M. Séguin, his nephew, dates from the earliest years of this century.

From this *ensemble* of discoveries and scientific labours proceeded the doctrine of the purely mechanical nature of material phenomena; the hypothesis of ether, a unique fluid by means of which are accomplished the transformations of motions; and, finally, the theory of the conservation of energy. But it would be wrong to look upon these great ideas, of which the researches now going on are gradually furnishing the confirmation, as belonging to the present century. As to their general principles, and if we except errors of detail, all these ideas are clearly expounded in the works of Descartes. The highest ambition of contemporary

[1] *Journal des Savants*, de Juin, 1874, page 416, L'ouvrage de M. Séguin est de 1839.

physics is to realise the programme which he traced with a firm hand, and which he thought he had carried out because he had traced it. Faraday "saw in the universe only a single force obeying a single will."[1] This is precisely the thought which guided Descartes in his struggle against substantial forms. M. Helmholtz affirms that "what we must look for in the last resort is the explanation of the laws of motion," and that, amid all the waverings of science, there is still one law which may be confidently stated, namely, "the law of the conservation of force."[2] Here are theses which Descartes would have subscribed, because he had expressly formulated them. If this philosopher could have been present at the Congress of the French Association for the Advancement of Science, assembled at Lille, in 1874, and heard M. Würtz, he would have learnt that "it is in the motion of atoms and molecules that is sought now-a-days, not only the source of chemical forces, but the cause of the physical modifications of matter, of the changes of state which it may undergo, of the phenomena of light, heat, and electricity of which it is the support." He would have heard it proclaimed, by one of the most legitimate authorities, that the power of motion passes from one body to another, and manifests itself under different forms, "but that we never see it disappear or grow weak."[3] For all that belongs to detail, precision, special theories, Descartes would have had to sit as a humble learner at

[1] "Éloge Historique de Michel Faraday," par M. Dumas.
[2] *Revue des Cours Scientifique*, du 8 Janvier, 1870.
[3] *Revue Scientifique*, du 22 Août, 1874, pages 174 et 175.

the feet of the learned Dean of the Faculty of Medicine of Paris; but for the direction to be given to researches, and the general conception of physical phenomena, he would have had the right, his works in his hand, to claim as his own the great thoughts which govern contemporary science. Take a sheet of paper divided into two columns. On one side write the most general affirmations of the physics now prevailing, and on the other you may put the same affirmations extracted from the works of Descartes and his immediate successors. You will thus easily become aware that the theories which we have regarded as new are simply revived. The seventeenth century invented them; our own, aided by the labours of the eighteenth, confirms them, by experimental inductions based upon a rich treasure of observations. It is sometimes said, "It is nothing to have an idea; to prove it is everything." This way of thinking provokes a very simple reflection. One may have an idea before it is possible to prove it; but how shall we prove an idea before possessing it at all? To have a false idea is nothing, of course; to discover a true idea is the first condition of the progress of science. If Columbus had died before reaching the shores of the New World, leaving his thought to some more fortunate navigator, would he any the less have been the author of the discovery of America? The idea once thrown out, the captain of any vessel might have confirmed it; but to be confirmed it must needs have been thrown out. The fundamental principles of modern physics were proclaimed to the seventeenth century, and they have not been discovered anew in

our time in a manner independent of their first announcement. The savants of our day have been subject to the influence of their illustrious forerunners, some without knowing it, others with acknowledgment. Fresnel, for example, in the introduction to his "Mémoire sur la Diffraction de la Lumière," declares that the theory which he adopts and maintains is, in contradiction to the ideas of Newton, the doctrine of Descartes, Hooke, Huyghens, and Euler. Our epoch is that of the developments of science, and its application to industry; but the opinion which reckons the origin of the general principle of modern physics as belonging to the nineteenth century, is an error comparable to that of a geographer who should place the sources of the Rhone at Bellegarde, where the waters of that river, after having, for a brief while, been hidden beneath the surface of the ground, come forth again to the light.

The fame of Descartes has passed through phases resembling the fate which has befallen his doctrine. When he replaced by his clear explanations the obscure theories of substantial forms, he excited a genuine enthusiasm. The learned world was dazzled both by the truth of his fundamental ideas, and by the daring nature of his system. His very errors, as Laplace remarks,[1] had a grand character which favoured their success. Men thought, as he had thought himself, that the universal explanation of nature was discovered, and that the edifice of science was well-nigh completed. It was not only savants who enlisted under the banner

[1] "Exposition du Système du Monde," livre v. chap. 5.

of the new philosophy, but people of the world of both sexes. La Fontaine made himself the organ of this great current of opinion, and wrote thus:—

"Descartes with pagans would a god have been—
No mortal; and now holds a place between
Mere man and spirit: as some folk we know,
'Twixt man and oyster might as fitly go—
Mere beasts of burden!"[1]

Pascal made a clear distinction between the part of Cartesianism which is true—the determination, namely, of science—and the explanations of detail, which were at variance with the truth: "We must say in general, that takes place by form and motion, for that is true. But to say what, and compose the machine[2]—that is ridiculous, for it is useless and uncertain and distressing."[3] What Pascal distinguishes here, with an accent of bad humour which is without excuse, is precisely what there was a danger of confusing. The fundamental principles of Cartesianism were rejected, because the system of vortices was found to be incorrect. The triumph of Newton's disciples brought on a blind reaction in general opinion against the reputation of Descartes. Maclaurin, speaking of the Cartesian system, employs the term *rhapsodie.*[4]

[1] "Descartes, ce mortel dont on eût fait un dieu
Chez les païens, et qui tient le milieu
Entre l'homme et l'esprit, comme entre l'huître et l'homme
Le tient tel de nos gens, franche bête de somme."
—Fable i. du livre x.

[2] *Mais de dire quels, et composer la machine.*

[3] "Pensées," édition Fangère, tome i. page 181.

[4] "Exposition des Découvertes de Newton," page 69.

Voltaire, witness of the eclipse which a great renown was undergoing, speaks "of that master, René, who is forgotten now-a-days."[1] There is in this line a tone of melancholy, and of homage for the great man forgotten; but the pitiless railer elsewhere writes:—

> "He set demurely forth to view
> A brilliant heap of errors new,
> And willed that they might hold the place
> Of babblings of the ancient race."

The Cartesian physics and metaphysics were alike despised, and their author was looked upon as having written a double romance—that of the soul, and that of nature. In proportion as the fame of Descartes became obscured, that of Bacon shone with an ever-increasing brightness. It was become fashionable to shower upon him "eulogies, in some sort fanatical, in every preface, in every book of physics, physiology, and philosophy."[2] We may say that opinion reached its extreme point in this direction at the time of the normal schools, when Professor Garat, wishing to silence St. Martin, who was plying him with sundry objections, threw in his face, almost as an insult, the epithet of Cartesian.[3] It is right to remark that Condorcet resisted this general stream of opinion, and maintained with much firmness the position due to Descartes. He expresses himself as follows:—

"Confining himself exclusively to the mathematical

[1] Les Systèmes, dans les "Satires."

[2] "Portraits Littéraires." Par Sainte-Beuve. Joseph de Maistre.

[3] Voir "Les Ecoles Normales, Livre National." Débats, tome iii. pages 18 à 25.

and physical sciences, Galileo could not impress on men's minds the movement which they seemed to be waiting for. This honour was reserved for Descartes, that ingenious and bold philosopher. Endowed with a great genius for the sciences, he joined example to precept, by giving the method for discovering and recognising truth. He showed the application of it in the discovery of the laws of dioptrics; those of the impact of bodies; finally, of a new branch of mathematics destined to widen all the boundaries of that science. He desired to extend his method to all the objects of the human understanding;—God, man, the universe, were in turn the subject of his contemplations. If in the physical sciences his advance is less sure than that of Galileo; if his philosophy is less prudent than that of Bacon; if he is open to the reproach of not having profited enough by the lessons of the one and by the example of the other, so as to distrust his imagination, not to interrogate nature otherwise than by experiments, not to believe anything but calculation, to study man instead of divining him,—the very audacity of his errors served the progress of the human race. He agitated the minds which the wisdom of his rivals had been unable to awaken." [1]

We have seen that Laplace expressly ascribes to Descartes the conception and origin of mechanical astronomy, of which he was himself to place the topstone. M. Biot attributes to him, in a more general manner, the conception of a mechanical system of

[1] "Esquisse d'un Tableau Historique des Progrès de l'Esprit Humain," huitième époque, à la fin.

physics:—"In the midst of all the errors of Descartes, we must not fail to recognise a grand idea, which consists in having attempted, for the first time, to treat all natural phenomena whatsoever as being a simple development of the laws of mechanics."[1] Here are indications of a legitimate reaction against the unjust disparagement of a great renown. This reaction has made way in proportion as contemporary science, relinquishing the notion of a vacuum, upheld by the followers of Newton, has revived the theory of a subtile matter, under the name of ether, demonstrated the theory of luminous undulations, affirmed heat to be only a motion, and finally proclaimed the conservation of energy. It sufficed to open the works of Descartes to be assured that he had announced these grand theories of modern physics, and that if he was mistaken as to the method and as to a multitude of affirmations of detail, yet he had fixed the guiding principles of researches. This is what M. Pontécoulant said, in express terms, in the introduction to his "Théorie Analytique du Système du Monde," published in 1829: "Descartes deserved the gratitude of future ages by opening a new career to the meditations of the human mind, and pointing out the road which his successors were to follow with so much glory." To point out the road is surely the work of a leader, of a founder. M. Joseph Bertrand justified, and to a great degree advanced, the return of public opinion towards a just appreciation of the history of science, when, in 1869, he set forth the bases of modern physics, and gave to

[1] "Biographie Universelle."

his work a title which would greatly have surprised Garat—"Renaissance de la Physique Cartésienne."[1] In fact, Descartes, two centuries ago, traced the programme of all that we know, and of all that we are seeking to know. When we have drawn up the catalogue of his errors, we shall of force confess, in the presence of facts, that he is, to use an expression which I borrow of M. Renouvier, "the great speculative physicist" who laid the foundations of modern science.

Descartes marked out the object of science; but his work had to be completed and corrected. His glory must not cast into the shade that of Galileo, of Kepler, and even—all reserves made—what must stand good of that of Bacon. If we consider not only the mother-idea,[2] the guiding thought, but, in a general way, the development of science, modern physics had several founders. These founders did their work under the influence of philosophical views which will form the subject of the following study.

[1] *Journal des Savants* de Novembre, 1869.

[2] *L'idée-mère.*

THIRD ESSAY.

The Philosophy of the Founders of Modern Physics.

IT follows as a consequence from our Study last preceding that modern physics, prepared by the intellectual movement of previous centuries, receives its development, and assumes its proper characters, at the beginning of the seventeenth century. Those best qualified to speak agree that this period was one of the great epochs of the history of science. Humboldt is describing "the giant strides" which the human mind made in the seventeenth century, and he writes: "The mathematical study of nature is founded and supported upon solid bases. . . . From that moment labour goes on without interruption in the world of thought"[1] Herschell speaks in the same way: "Science then received an immense impulse. One would have said that the genius of man, for a long time held in check, was escaping from its trammels; that it was at length springing forth into the universe; that it was beginning to clear a virgin soil, and to lay bare the treasures buried in its bosom. . . . Each one took part in the search, and soon there opened a new era full of enthus-

[1] "Cosmos," ii. 364 et 365.

iasm and of marvels, to which nothing comparable is found in the annals of the human race.[1] Liebig expresses a very similar opinion, and says that the first quarter of the seventeenth century is "the most brilliant and memorable period in the history of the sciences of observation."[2] Describing the same epoch in a somewhat broader way, he characterises it as "the most remarkable century of the Christian era," and he goes on to say: "Great discoveries in the heavens and upon the earth had impressed a powerful movement upon the mind of the European nations; it was the epoch of the Keplers, the Galileos, the Stevins, the Gilberts, the Harriots,—that is to say, of the founders of what constitutes in our days of astronomy, physics, mechanics, hydrostatics, as well as the theories of electricity and magnetism."[3] This, then, according to the opinion of the most competent judges, was the moment when the modern science of nature took its rise; it is the epoch of the founders. Whence proceeds the extraordinary impulse which the human mind then received?

The opinion is pretty widely entertained that philosophy had no part in this scientific movement: "The savants," says M. Claude Bernard, "make their discoveries, and pursue their theories and their science, without the philosophers;" and a few pages before: "To find the truth, it is enough for the savant to place himself face to face with nature, and interrogate her,

1 "Discours sur l'Étude de la Philosophie Naturelle." Deuxième Partie, chap. iii.

2 "Lord Bacon," traduction Tchihatchef, page 234.

3 "Lord Bacon," pages 3 et 4.

by the method of experiment, and in the use of more and more perfect means of investigation. I think that, in this case, the best philosophical system is to have no system at all."[1] To this thesis of method is often joined a thesis of history. It is affirmed that to break with philosophical doctrines has been the condition of satisfactory experimental theories. The most thoroughgoing expositor of this way of thinking is Auguste Comte, who tells us that we must break altogether with metaphysics, in order at length to inaugurate the positive era of thought. The character of this final period of the human mind is to be that, renouncing every principle anterior or superior to experience, we confine ourselves to the simple "co-ordination of facts."

An opinion which rests for support upon the preceding idea would make the science of nature to be contrary to spiritualistic doctrines, so that what we have to do is, not only to keep clear of philosophy, but to deny all philosophy which acknowledges for the universe a cause and a destination. Then it is declared that the idea of God arrests the progress of the human mind; atheism is favoured as subservient to the interests of science, just as certain contemporary demagogues demand the abolition of the idea of God with a view to the renovation of society.

These theses are false in principle and in fact. Science cannot make progress except under the influence of principles which direct observation: this is the question of principle; we shall come to it by-and-by.

[1] "Introduction à l'Étude de la Médicine Expérimentale," Troisième Partie, chap. iv. § 4.

We will begin with the question of fact. The affirmation that the science of nature had its beginning in a rupture with all *à priori* principles is an historical error. Modern science took its rise under the influence of a determinate doctrine, of which the two essential theses are the reality of the soul and the existence of the Creator. Well, to understand this true paradox, we must guard against a confusion of ideas; then take into consideration a truth upon the false interpretation of which is grounded a notable error.

There has existed a relation historically certain between the idea of God the Creator and the foundation of science; but it is the idea of God which is in question, the solution of the philosophical problem contained in religious faith, and religious dogma in its totality. The subject of physics belongs to no Church; it is not the product or the confirmation of any dogmatic symbol, but it is theistic in its historical origin, and its guiding principles. It is so already among the thinkers of Greece, who proclaim more or less the Divine unity in the face of idols; but it is so in a manner incomplete, as is the theism of the philosophers; it is so in the modern world in a manner complete and decided. The relation between the conception of the principle of the universe and the science of nature is easy to establish; but to bring into the question the traditional data of this or that particular form of worship would be a grave confusion of ideas which it was desirable to prevent.

The truth to which I have made allusion is—that modern science required, in order to its foundation, that

it should be set free in three several particulars: First, from theology; it was necessary to relinquish the attempt to educe a system of physics from the interpretation, more or less correct, of the sacred writings, and to conclude that the earth was without motion because theology taught the motion of the sun. Secondly, from the authority of Aristotle; it was necessary to give up saying that there could not be spots in the sun, because Aristotle had said that the heavens were incorruptible. And, thirdly, from the *à priori* method; it was necessary to leave off confounding the processes of physics with those of mathematics, and give up proclaiming the circle to be the most perfect of figures, in order to infer the circular form of the orbits of the planets. It was indispensable to acknowledge that observation and experience are the necessary bases of every solid theory, and the only legitimate means of controlling the conjectures of the human mind. This grand idea of the enfranchisement of science, and of the supreme authority of facts is particularly connected with the name and the work of Bacon. It is not true, as Bacon has very often said, and as his admirers have repeated, that he appeared as a sudden light in the midst of thick darkness. The necessity of experiment had been understood and practised by several of his contemporaries. Those who would compare him to a sun, as was wittily remarked by Joseph de Maistre, must allow that, when the sun rose it was at least ten o'clock in the morning.[1] But, if Bacon did not first discover the necessity of experiment, he

[1] "Soirées de St. Pétersbourg."

proclaimed that truth with an incomparable *eclat*, and, by proclaiming it, contributed to spread it abroad. We must interrogate nature and not the texts of ancient authors. We must study the facts which it is desired to explain, and not build theories upon mere ideas. We must break with illegitimate authorities and with the pretension to construct *à priori* the system of nature. This is what Bacon said, and what, at his epoch, amongst others, Kepler and Galileo did. Science had its birth from the abandonment of the method which took, as its point of departure, whether texts, or conceptions purely rational; this is the real fact. The error which is connected with it is the supposing that science can proceed from the mere observation of phenomena. Observation alone could not supply any law or any theory, because laws and theories are not objects of sensible perception. We must interrogate the book of nature, no doubt, and not the texts of the ancients; but nature is not a book in which laws are so written that it needs only the use of one's eyes to see them. Voltaire said with reason:—

> "Nature is dumb; in vain we question her."[1]

It is the mind which puts questions; it is the mind which attempts answers, and which must submit them to the control of experience. The field of conjectures is unlimited. What is it that directs the mind in its essays? Determinate principles which, as regards experience, are *à priori*, but principles simply formal

[1] Poëme sur le "Désastre de Lisbonne":—

> "La nature est muette, on l'interroge en vain."

which set thought upon a certain track, without offering any basis to deductions, by means of which a system may be constructed. It is easy, by examining the two following cases, to understand the difference between elements of systems to be excluded, and principles to be maintained. To start with the idea that the planets move according to a perfect form, and thence to infer that their orbits are circular, is a false conclusion, which is the result of an erroneous method. To start with the idea that nature is governed by general laws, and to conclude that we must always seek to reduce apparent exceptions to the rule, is a right conclusion, which furnishes a rule of excellent method. This right conclusion cannot serve as a basis to any particular affirmation; all it does is to give a direction to the essays of thought—essays which must remain subject to the control of experience.

It is by the influence of principles of this nature that the legitimate action of philosophy upon science is manifested. What are the principles which directed the founders of modern physics in their researches?

The Guiding Principles of Physics.

The first guiding principle of all the sciences is the conviction that the phenomena are governed according to the laws of the understanding. Our understanding does not possess in itself the sources of the reality; we can discover nothing by combining simple ideas. In order to know nature, we must observe it: but observation gives scientific results only because the universe is

rational. If in nature four bodies and three bodies could make eight bodies, and not seven; if in nature the third side of a triangle did not vary, according to the laws of geometry, with the length of the two other sides, and with the size of the opposite angle, it is clear that science would be for ever impossible. Nature is governed in a way conformable to the laws of our understanding: and such, therefore, is the fundamental principle which directs all the researches of thought. This principle often remains unperceived, because it is instinctive, and disappears beneath the veil of the profoundest of habits. It is, in fact, supposed by the first *why* of the infant, as well as by the application of the highest formulæ of the infinitesimal calculus to physical phenomena. The child who asks the *why* of a fact asks one to *give him a reason* for the fact, which is as much as to say that he admits the conformity of facts and of the laws of the reason. This is the result of an instinct essential to the intellectual nature, in the absence of which no research could take place at all.

With this fundamental principle are connected four others, which are, in a manner, included in it, and which we will now pass in review.

1. *Principle of Causality.*—All that is produced has a cause;[1] every phenomenon supposes an antecedent. From nothing proceeds nothing: we must, therefore, go back from one action to an anterior action which accounts for it. But this going back of thought of necessity has a term. This last term, which will become the starting-point of all explanations, will be a state of

[1] *Une raison d'être.*

things considered as primitive, from which everything will be a deduction, and which will not itself be deduced. In the study of physical nature, the point of departure will be a state of matter regarded as primitive, and laws of motion considered as primordial, as was said in our first essay, when we were discussing the nebular hypothesis.

Researches which should go higher, and the object of which would be to reach to the cause of the existence itself of matter and of the laws of its motions, would exceed the limits of physics and enter the domain of philosophy.[1] The principle of causality is the fundamental basis of science. M. Helmholtz informs us "that he sought to determine all the relations which can exist between the actions of nature, according to the principle of the *impossibility of creating anything out of nothing*."[2] All savants do the same when their affirmations retain a serious character. To admit the action of non-existence; or, which comes to the same thing, to conceive of chance as an efficient cause in the explanation of phenomena, is to cut the very root and sinews of human thought.[3]

2. *Principle of Constancy.*—This principle applies to existences: we admit that the universe is composed of elements forming different classes the properties of which are fixed. It applies to laws: we admit that the same antecedents being given, the same consequence will follow; this is what is called *determinism.*

[1] See the Fifth Essay.

[2] "Mémoire sur la Conservation de la Force," page 23.

[3] *Couper la racine a maîtresse.*

The principle applies to space and time: we admit that the primitive classes and the primitive laws are the same everywhere, and always. The problem of science is to explain the variation of things by fixed laws, combined with elements of invariable nature. This is the basis of all inductions, and of all deductions. Without this basis science would be impossible. It is manifest that if, in circumstances supposed absolutely identical, water did not become ice or vapour at the same temperature; if the laws of motion were not the same in Europe as in Asia, and were not to-day what they were yesterday, any general affirmation would become impossible.

Absolute determinism stops before the consideration of free causes, because the idea of a free cause is that of an antecedent which involves the possibility of different consequences. A naturalist will endeavour to give account of the elevation of mountains at the surface of the globe by the fixed laws of nature; but it will not enter his head to give account of the elevation of the tower of a cathedral without supposing the intervention of the human will whose determinations are due to other sources than natural phenomena. The principle of causality subsists in all cases; but it varies in its application according as it is applied to beings deprived of all initiative, or to beings which carry in themselves an initial force by virtue of which they are, in part at least, the cause of their own acts. The doctrine of the inertia of matter being admitted, it results from it that physical phenomena are submitted to an absolute determinism.

3. *Principle of Simplicity.*—This is a principle admitted in the schools of the Middle Ages, expressly retained by Galileo, and adopted by Newton in the "Principia," that in the study of nature we should always set out with the idea that the multitude of effects is produced by a small number of causes, and reduce the number of those causes as far as possible. It is in virtue of this principle, conscious or unconscious, and in some sort instinctive, that we admit that science takes a step forward when it rises to higher generalisations, that is to say, when it succeeds in reducing the number of classes and the number of laws of which it makes use for the explanation of phenomena. A beautiful application of the principle also is, the theory of least action, according to which natural effects are obtained with the least possible expenditure of forces—a marvellous economy, of which we find examples in the laws which regulate the phenomena of the reflection and refraction of luminous rays.

4. *Principle of Harmony.*—Harmony, or the relation of things between themselves in a hierarchical order, is the manifestation of unity maintained in multiplicity. Nothing is isolated; everything acts upon everything, and everything is subject to the influence of everything. The different classes of beings and the different laws which govern them are in constant relations, which, while they do not allow us to confound them, do not any the more permit us to separate them. To discover the relations which would not otherwise be perceived, is one of the most essential indications of scientific genius. This principle is expressed by a word

which is often upon our lips, without our comprehending its profound significance. The word *universe*, by which we designate the totality of existences, has as its etymological meaning, according to our best accredited philologists, "*that which is turned towards one.*"[1] To conceive of all things as turned towards a unity which places them in a mutual relation, is the highest expression of the idea of harmony. Charles Bonnet has expressed it in these terms at the beginning of his "Contemplation de la Nature": "I contemplate the universe with a philosophic eye. I look for the relations which make of that immense chain one single whole."

Such are the principles which directed the researches of the founders of physics. The principle of finality, which plays so large a part in biology, and in the general theory of the universe, appears but little in special physics, and only has a place in that science when it rises to the height at which it is transformed into philosophy.

To these guiding principles has been added, in the foundation of modern science, a definitive conception of the proper object of physics, that is to say, of matter; the idea of inertia. Matter is a force since it occupies space; but the elements of matter have no spontaneity, no power to modify their own proper motion, no power to produce psychical phenomena. Sound, heat, light, colours, are relations between the various motions of matter, and the soul capable of sensation from them. Thus it is that the distinction between the soul and the body, between spiritual phenomena and corporeal

[1] Ce qui est tourné vers l'un.

phenomena, is necessarily found to be stated, in the conditions of modern science, at the beginning of all treatises upon physics.

The ideas which I have just passed in review, more or less distinctly stated, more or less faithfully applied, have directed the researches of the founders of modern physics. They have not been recognised in the same degree by every one of these illustrious savants; some of them have failed to take account of one or another of the principles indicated; but these principles have presided at the birth and development of science considered in its *ensemble*. What is the character of these leading ideas?

The idea of the inertia of matter was at first, as we shall see, a conclusion deduced from philosophical principles: it is become in the sequel an hypothesis amply confirmed. As to the four guiding principles, they are neither immediate data from experience, nor yet axioms of the reason. Experience has confirmed these grand ideas, but the experience which has confirmed them could only have been derived from their preliminary application. We will repeat in this connection words already quoted in our first essay: "The great mass of phenomena," says M. Helmholtz, "are more and more reduced to order under the guidance of science. Doubts concerning the existence of immutable laws of phenomena are every day disappearing, while discoveries are being made of laws ever greater and more general."[1] Humboldt on his part writes: "The image of the Cosmos which was originally revealed to the

[1] *Revue des Cours Scientifiques*, du 8 Janvier, 1870.

inner sense as a vague presentiment of harmony and order in the universe, is at this day presented to the mind as the fruit of long and attentive observations."[1] These two passages complete one another, and in their union present to us the total truth.

Order and harmony in the universe revealed themselves to observation, because the human mind sought for them by virtue of a confused but real presentiment. Without this presentiment—no research; and without research—no discoveries. We are able to say nothing on the subject of the general result of science which was not foreseen by Pythagoras, in ancient days, and boldly affirmed, in modern times, by Descartes and Leibnitz. Experiment demonstrates theses which it does not propose. These theses appear at first in the instinctive and spontaneous form, to pass in course of time to the settled and deliberate form. In a manuscript of Professor Thury's, which I quote with the author's permission, I have met with the application of this general truth to a special science—mechanics: "The general laws of mechanics have been deduced from the attentive observation of facts, and from a small number of very simple, but well-chosen experiments. It must, however, be acknowledged that these experiments and facts do not establish the general laws in a certain and sufficiently accurate way except upon the hypothesis of very simple laws; but the idea that such an hypothesis is necessarily conformable to the truth seems to have been the profound feeling of the men of genius who founded mechanical science, and

[1] "Cosmos," tome i. page 2.

subsequent labours have proved that this feeling had not misled them." Without the feeling which conducted the founders, the subsequent labours which have experimentally justified their theories would have been arrested at their source.

If the guiding principles of physics are not experimental truths, which would suppose the cause to be the result of the effect, no more are they axioms. The principle of causality alone belongs to the class of truths immediately evident to the reason. The three other principles have no immediate evidence, and what proves this is that they have not, like the principle of causality, a universal application. The principle of constancy does not apply to free beings except in this sense, that liberty is for them an essential and permanent attribute; but, by reason of this very liberty, their actions do not fall under the law of an absolute determinism. The principle of simplicity no doubt directs biological studies; but it is a question much disputed whether this principle is not a source of error to savants who seek to establish the unity of origin of living beings, and especially the unity of organised matter, and of inorganic bodies.

The principle of harmony does not apply to the present state of humanity, if we believe in the reality of evil; at least it applies to it only in the sense of the conditional harmony of good and of happiness, of evil and of suffering. When Victor Hugo opposes—

> "The song of nature to the cry
> Out-wrung from human destiny,"[1]

[1] Ce qu'on entend sur la montagne, dans les "Feuilles d'Automne."

he gives expression, in a poetical form, to an experience which a serious philosophy must take account of. The three guiding principles last named are *postulates* in the science of nature. They are not necessary; they are not capable of a real experimental demonstration. "It is not a case for evidence, but for faith," as M. Charles Secrétan says.[1] The human mind carries in itself the germ of those principles which experience develops by confirming them; it advances under their influence to its encounter with nature. These principles are, in a manner, organs of intellectual vision placed in harmony with the real order of phenomena, as the eye is in harmony with luminous waves. To believe that light creates the eye, and to believe that experiment creates the principles which direct it, are two similar errors, which consist in reducing falsely to a single element the two terms of a relation.

The guiding principles exist in the mind in a virtual condition; it is only experiment which brings them into actual exercise. Once put into action, they are more or less recognised and discerned by reflection, and the reflection which discerns them is enlightened or obscured by the influence of certain doctrines. This consideration throws a strong light upon the line of demarcation which separates, in a scientific point of view, ancient and modern times.

[1] "Précis Elementaire de Philosophie," § 77.

Influence of Religious Beliefs upon the Guiding Principles of Physics.

The guiding principles of science existed, in some degree, in the minds of the philosophers of Greece, but polytheism presented an obstacle to the development of these principles, and to their general application. Polytheism, affirmed by religious tradition, was fortified by the poetical spirit, which is everywhere favourable to the personification of abstract ideas, and which in Greece was still more so than elsewhere. So far as common opinion placed a divinity at the origin of each phenomenon, it held the spirit of science in check: the need of causality felt by the reason was satisfied, but the idea of the infinite diversity of causes, not free only but capricious, put a stop to researches. The sentiment of unity is powerfully manifested in the school of Pythagoras and in that of Xenophanes. Socrates celebrates "the supreme God, Him who made and who directs the universe, who maintains the works of creation in the flower of youth and in a vigour ever new, who forces them to obey His orders, and forbids them to go astray."[1] "The nature of some of the accusations directed against him, the reproach which was cast upon him of substituting the natural explanation of phenomena for the action of the deities, indicates the struggle of philosophy against the religious polytheism. But the ancient mind was not for the most part successful in disengaging the idea of the unity of

[1] "Les Entretiens Memorables de Socrate," livre iv. § 10.

the principle of the universe from dualism, unless by formulating it in the direction of a pantheism, which allies itself easily with idolatry. Just views relative to the science of nature are found to be but little developed, and remain the privilege of a small number of intelligences."

During this period of history, the full idea of the Creator was affirmed by the people of Israel. The author of the cxlviii. Psalm poetically invites all creatures, and specially all the stars of heaven, to praise the Lord, for, saith he, "He commanded, and they were created: He hath made them fast for ever and ever: He hath given them a law which shall not be broken."[1]

The Psalm cxix. speaks also of laws established by the Creator: "They continue this day according to thine ordinance; for all things serve Thee."[2] Here we find the affirmation of the unity and constancy of the universal cause. Still, science was not developed among the people of Israel. The basis of observation was wanting: and then the power of the sovereign Being drew by itself the general attention, and could be considered as a sufficient explanation of the phenomena; the notion of the cause absorbed that of the laws. The idea of the constancy of the creative act manifesting itself by general and fixed laws, although, as we have just seen, it had been pointed out, was thrown into a back-ground remote from thought. Now, it was indispensable for the formation of science that this idea should be set in a full light; and this was to be the case by the development of monotheism transmitted

[1] Verses 5 and 6. [2] Verse 91.

by the people of Israel to the Christian world. The conception of nature as the manifestation of a single will is expressed as follows by one of the most ancient Fathers of the Church, Clement of Rome, in his Epistle to the Corinthians:

"Let us contemplate in thought, let us regard with the eyes of our mind, His will ever lovingly desirous of peace; let us see how that love manifests itself in His works.

"The heavens set in motion by His mighty hand, remain peaceably subject to Him.

"Day and night supply the light which He has allotted to them, and never do injury one to the other.

"The sun, the moon, the choirs of the stars, describe, according to His commandment, in a perfect harmony, without the slightest deviation, the orbits which He has marked out for them.

"The earth, always fruitful, produces, each season, according to His will, abundant nourishment for man, and for all animals, without resistance on its part; without the least change from the laws which it has received.

"The abysses which we cannot penetrate, the depths of the earth which we cannot unveil, have the like respect to His behests.

"The mass of the sea, boundless and fathomless, after the ordinance of the Creator, swells, rises in mountains, and never overpasses the barriers placed about it: such is the command which it has received, and which it obeys; for the Lord has said to it: *Hitherto shalt thou come, but no farther: and here shall thy proud waves be stayed.*

"The ocean, of depth impenetrable, and the worlds scattered beyond the ocean, are governed by the same laws.

"The various seasons, spring, summer, autumn, and winter, peacefully succeed one another.

"The winds, held in equilibrium, discharge their duty in their times, and do not meet with the slightest obstacle.

"Springs always gushing forth, created for the service of man's life, and the health of his body, cease not to present to him their inexhaustible waters, and to sustain his existence.

"Thus it is, that the great Worker, the Master of the universe, has willed that all shall be maintained, in peace and harmony."

Here we have the supreme God of Socrates disengaged from all clouds, and become the sole Creator, the cause of the cxistence of the universe, and the principle of its stability and its harmony.

Monotheism succeeded in gaining a hold on men's minds in general only at the cost of great efforts and prolonged struggles. The work of Irenæus, Bishop of Lyons, is devoted to the conflict with polytheism, not among pagans only, but among several Christian sects, which corrupted the new doctrine by an admixture of ancient notions. During the Middle Ages monotheism was established in the general belief. This period of history offers to observation, in regard to the development of the human mind, these two capital facts: the logical culture of the understanding, under the discipline of Aristotle; and the definitive establishment of the

idea of the unity of the principle of the universe. This was the union of two essential conditions of science which up to that time had been separated—the monotheism of the Hebrews, and the rational tendency of the Greek thinkers. This union was the long and laborious work of the first fifteen centuries of our era; but the Middle Age pursued a vicious method, and the absence of liberty arrested the onward advance of thought. It was necessary that it should be set free from the undue influence of scientific authorities, and from the pretensions of the *à priori* method. When this enfranchisement was effected, modern science took a rapid start by the employment of the reason, fortified by logic, and directed by the thought of the Divine unity. There has not been, therefore, as we are commonly taught, a total absence of continuity between the labours of the scholastic philosophy and the rise of natural science. Those who speak of the Middle Ages as a period of unrelieved darkness, to which they set in contrast the sudden appearance of light, deceive themselves. This way of putting things, if effective, is not historically true; and it is time we understood that the epoch which saw the cathedrals built accomplished a scientific work deserving of respect. The intellectual instrument had been slowly prepared; observation and experiment were to furnish it with indispensable material; but the mass of observations and experiments only came after the awakening of the modern mind, and afforded the confirmation, not the basis, of the great theories which at this day we consider as the truth. The matter in question here is not at all that

of theological doctrines. The influence exercised upon the scientific spirit by religious belief is a fact to be ascertained. The fact once established, every one remains at liberty to interpret it in his own way; but no one has the right to deny it. M. Du Bois-Reymond said, a few years ago, to the German naturalists assembled at Cologne: "Though it may sound like a paradox, modern science owes its origin to Christianity." After having set in contrast to the polytheism of the ancient world the pure and complete theism which Christianity has spread through the world, the Berlin professor went on to say: "This idea of God, handed down for ages from generation to generation, came at last to react upon science itself, and, by accustoming the human mind to the conception of a unique reason for things, kindled in it the desire to know that reason."[1]

The founders of modern physics have all been placed under the influence of their faith in God the Creator, and have connected with that faith the guiding principles of their researches. One often hears it said that there exists between science and religious ideas a fundamental opposition. I have always been struck with the paradoxical character of this affirmation, in the face of the unquestionable fact that all the founders of modern science have been theists in the most decided manner. It was evident then, for me, that one may be *savant* and believer: it remained to be seen whether these two qualities, that of believer and that of savant, were merely in juxtaposition in such men as Kepler,

[1] *Revue Scientifique* du 19 Janvier, 1878, page 676.

Descartes, and Galileo, or whether they were bound together in a logical relation. An attentive study of the subject has led me to the clear conviction that, on the condition of the observation of facts, science had its origin under the influence of these two ideas: the immaterial nature of the soul, and the existence of God. These ideas are disconnected from religious dogma as a whole, and constitute what I call the philosophy of the founders. How have these two beliefs acted upon scientific development? In the following way:—

The unity of God admitted, the universe is the product of a single will realising the plan conceived by a unique intelligence: this is the solid foundation of the principle of harmony. This principle was certainly not unknown to Pythagoras, to Plato, and to Aristotle; but its full development was arrested in the productions of ancient wisdom, whether by the polytheism of the popular religions, or by a remnant of dualism from which Aristotle, and even Plato, did not succeed in setting themselves entirely free. The distinct affirmation of the unity of the Creator offered a firm basis to the idea of universal harmony, and gave to the reason a motive for confidence in its own value. This is the fact which I had ascertained by my own studies, and the confirmation of which I met with in the words quoted from M. Du Bois-Raymond.

The unity affirmed in the Christian world is not the abstract unity of oriental and Alexandrine pantheism; it is not a unity which is that of the reason, unconscious in nature, and becoming conscious in humanity. Our mind is capable of comprehending the universe in

a certain degree; but we are placed in presence of the works of a free power. To know the works of that power, it is necessary to observe them. Thus it is that the necessity of placing experience at the basis of our theories, and of seeking in it the only legitimate control of our systems, finds its support in the idea of the liberty of the Creator. We have here, it might seem, a simple matter of good sense; but history teaches us how much difficulty this assumption of common-sense has had in obtaining its place in the scientific method.

Goodness, an essential attribute of the first and perfect Being, assures us that He has no will to deceive us. When, therefore, we are in presence, not of our own prejudices, our own factitious ideas, and the temerities of our own imaginations, but of the fundamental laws of the understanding, we are in presence of the truth. To believe in the reason is to believe in the harmony of realities and of the legitimate developments of our thought. This natural belief, shaken by scepticism, is confirmed by the consideration of the goodness of the principle of the universe. For one who considers things thoroughly, the formula, "I believe in the reason," and the formula, "I believe in the goodness of the Creator," are in substance one and the same.

The consideration of the Divine wisdom afforded support to the principle of constancy, and to the principle of simplicity. To multiply means beyond what is necessary is a want of wisdom; superfluity in the organisation of nature would be a mark of imperfection. Any change supposed in the immediate and direct work of the Creator would also denote an imperfection, since

that which is absolutely well made does not require to be changed. This is one of the essential bases of the study of nature, since it is the foundation of the idea of generality, and of the permanence of laws. It is important to remark, in order to prevent grave confusions of ideas, that the thought of the immutability of the Divine action has its legitimate application only in a domain in which it is understood that free acts do not intervene. To transfer this principle, without modifying its application, from the science of matter to questions raised by moral and religious phenomena, is to confound what it is essential to distinguish.

Belief in God the Creator is, therefore, a centre with which the guiding principles of thought have been connected by a logical bond easy to be recognised. This is not, I repeat, a theoretical affirmation, but the expression of a fact. It is the philosophy of the founders of science, who, in following out their researches, have produced modern physics. This affirmation would be misunderstood, and even rendered ridiculous, if it were taken to mean that natural philosophers, chemists, and astronomers have an habitual and distinct view of the principles which direct them, and of the belief which binds these principles together. An engineer, in the exercise of his profession, very seldom thinks of the fundamental laws of mechanics, which are at the base of all his labours, but he is continually putting them in practice. In the same way, the savant realises in his researches principles which he discriminates so much the less as habit had rendered them for him in a manner instinctive. The founders of science have

recognised and proclaimed principles more than their successors. It is their philosophy which, in its union with experience, has given birth to their physics. As I have said, all have not equally seen the principles in all their purity; it has even happened to them not to recognise one or another of the rules which must direct their thought. In what has gone before, I have brought together into one focus the various rays of light which have enlightened them; but it cannot be disputed that all have found in the idea of the Creator the confirmation and support of the natural tendencies of the reason. As this thesis affirms a fact, the proof of it can only be a detailed account of it.[1] This proof I shall give by passing in review the work of the men to whom the unanimous opinion of historians points as the founders of modern science.

Copernicus.

Alphonso, king of Castille, was staggered by the increasing difficulties of the astronomical system of Ptolemy, and the necessity of multiplying indefinitely the circles in which the heavenly bodies were made to move; and he said: "If God had called me to His council, things would have been in better order!" Copernicus had the same feeling, but gave a different

[1] For fuller details than are given in the following pages, the reader may consult the works here mentioned :—"Pensées de Descartes sur la Religion et la Morale," recueillies par M. Emery; "Pensées de Bacon, Képler, Newton, et Euler sur la Religion et la Morale"; "Pensées de Leibnitz sur la Religion et la Morale," par M. Emery. (These works have been recently reprinted at Tours.) "Les Fondateurs de l'Astronomie Moderne," par Joseph Bertrand; "L'Histoire de l'Astronomie dans ses Rapports avec la Religion," par Frédéric de Rougemont. Paris, 1865.

expression to his thought, which was very much the same as that of the king. "The wisdom of God," he said, "is so great that the erroneous character of our astronomical system is proved by its extraordinary complications." It was as impelled by this conviction of the supreme wisdom of the Creator that he consulted the ancient authors, in whose writings he found the germ of his hypothesis. The following are his remarks in his letter to Pope Paul III., which forms the preface to his work, "*De Revolutionibus Orbium Cœlestium*": "I had been meditating for a long time upon the uncertainty of the mathematical traditions relating to the motion of the heavenly bodies, and I began to be troubled that the philosophers, who sometimes scrutinise to such nicety the smallest things in existence, had been unable to arrive at a more certain explanation of the movements of the machine of a universe which has been created for us by the most perfect and most regular of Workers (*ab optimo et regularissimo omnium opifice*). I resolved, therefore, to read over again all the books of the philosophers which I could procure, to see whether none of them had thought that the motions of the spheres are different from what our professors of mathematics teach us that they are. I discovered, first of all, in Cicero that Nicetus had believed that it is the earth which moves. I found afterwards in Plutarch that some others had held the same opinion. . . . Thus it was that I also began to reflect upon the question of the earth's motion." Copernicus was a pious and charitable priest, and a savant of the first order. We see, by his own declaration, that the

thought of the wisdom of the Creator was the guiding principle of his scientific labour. The same remark applies to the greater part of the defenders of his doctrine. The struggle excited by the theory of the motion of the earth was long and sharp. To suppose that this doctrine triumphed by the mere fact that it gave a better account of the data of experience than did the system of Ptolemy would be a serious error. Tycho Brahe, an eminent observer, left the earth at the centre of the universe. The feeling which supported the partisans of Copernicus, and prepared for them a victory which the observations of the phenomena was destined to confirm, was that of the simplicity of the new theory, in its opposition to the ancient astronomy. It is easy to be assured of this by consulting the writings of the time. Simplicity of itself is satisfactory to the reason; but in all the founders of astronomy the instinct of the reason was fortified by faith in the wisdom of the Creator.

Kepler.

Kepler writes: "I admit nothing as true but what is true physically: this way of proceeding affords me great satisfaction now; and it is my glory which will survive me." Here we have the programme of a science very positive in the good sense of the term: but what is it which gives the impulse to Kepler's mind in the search after physical truth? His piety is well known. The same pen which defined what makes the glory of physical truth writes thus: "Happy those to whom it has been given to rise towards the heavens. They

learn to put but small value on what had appeared to them excellent, and to esteem above all things the works of God, and to find in the contemplation of them a true refreshment and a real joy. . . . I give Thee thanks, Lord, that Thou hast permitted me to rejoice and to be enraptured in the contemplation of the works of Thy hands. . . . Great is our Lord! Sky, sun, moon, and planets, proclaim His glory, be the language what it may in which ye give utterance to the praise! Proclaim His glory, celestial harmonies! . . . And thou, my soul, extol the glory of the Eternal as long as thou hast thy being." Such was the faith of Kepler. Now observe the relations of his faith with science. To know truth is, for him, "to rethink the thoughts of the Eternal," and he lays down the following maxim: "Since God is a unique Intelligence, the character of the laws which He has given to the universe must be unity and universality."[1] Great would have been his surprise if he had heard that the condition of a serious science is to break with every idea relating to the Divine world. His belief in the unity and infinite wisdom of the Creator urged him to the search for the harmony of the universe. On the other hand, he considered facts as characters traced by the Divine hand, so that he did not hesitate to sacrifice his most seductive theories from the moment that he found that experience did not confirm them. The history of his labours offers, in this respect, details of the highest interest.[2]

[1] See for Kepler: Rougemont, "Histoire de l'Astronomie," in particular, pages 88 to 89.

[2] See the "Logique de l'Hypothese," page 36.

The idea of God was, therefore, at once the principle from which his thought received its energy, and the source of his true humility. He thus affords an example of the union, under the full influence of monotheism, of two tendencies which Bacon and Descartes were to share between them.

Bacon.

There are two men in Bacon, and two men who often contradict one another. The pages of this great writer are full of the expression, assuredly sincere, of the most elevated sentiments; and he was seduced by weakness and vanity into acts the most reprehensible. Just so, in the matter of science, his works contain doctrines of a most decidedly spiritual character, and withal germs the development of which went to produce the materialism of Hobbes. The same diversity is to be observed in regard to his fame. He was the idol of the most irreligious savants of the eighteenth century; and a volume consisting merely of his pious thoughts has been put together. The truth is, those who tried to make of his writings a weapon for the enemies of religion, were forced to mutilate them. M. Lassale published, between the years 1800 and 1803, under the auspices of the French Government of that date, a translation in fifteen volumes of the works of Bacon; and he did not scruple to cut out of the text the passages in which were expressed Christian sentiments. After a time, no copies of this edition could be met with, because the successors of the publisher, by destroying them, imposed on themselves a considerable pecuniary sacrifice, rather

than allow a work which had been falsified to remain in circulation.[1] In spite of all his inconsistencies, Bacon was a man of thoroughly religious mind, and was very far from separating his science from his faith.[2] This may be judged of by the following passage taken from the preface to his principal work: "As the success of our enterprise in no way depends upon our will, we address to God, one God in three Persons, our most humble and fervent supplications, that, humbling Himself to behold

[1] "Notice sur M. Frantin," par M. Foisset. Dijon, 1864, page 10.

[2] Any doubt on this subject would be set at rest by the following passage from Dr. Whewell's work, "Indications of the Creator," which the translator is glad to quote, not only in support of the affirmation in the text, but in reply to remarks on Bacon scattered throughout the volume,—quotations from Liebig and others,—which, as an Englishman, he may be forgiven if he thinks unjustly disparaging of his illustrious fellow-countryman. At all events, the opinion of the author of both the History and the Philosophy of the Inductive Sciences will be listened to as worthy of respect: "When we have advanced so far, there yet remains one step. We may recollect the prayer of one, the Master in this School of the Philosophy of Science: 'This, also, we humbly and earnestly beg—that human things may not prejudice such as are Divine; neither that from the unlocking of the gates of sense, and the kindling of a greater actual light, anything may arise of incredulity or intellectual night towards Divine mysteries; but rather that, by our minds, thoroughly purged and cleared from folly and vanity, and yet subject and perfectly given up to the Divine Oracles, there may be given unto Faith the things that are Faith's.' When we are thus prepared for a higher teaching, we may be ready to listen to a greater than Bacon, when he says to those who have sought their God in the material universe: 'Whom ye ignorantly worship, Him declare I unto you.' And when we recollect how utterly inadequate all human language has been shown to be to express the nature of that Supreme Cause of the natural, and rational, and moral, and spiritual world, to which our philosophy points with trembling finger and shaded eyes, we may receive, with the less wonder, but with the more reverence, the declaration which has been vouchsafed to us: 'IN THE BEGINNING WAS THE WORD, AND THE WORD WAS WITH GOD, AND THE WORD WAS GOD.'" [Tr.]

the miseries of the human race, and our pilgrimage in this life, in which our days are short and evil, He will deign to dispense by our hand new benefits to the human family. Deign, therefore, O Father of all wisdom, who hast made the visible light to be the firstfruits of creation, and who, giving the finishing touch to Thy works, didst cause the light of intelligence to shine upon the human countenance,—vouchsafe to favour and direct this work, which, having its commencement in Thy goodness, shall have Thy glory for its end! Thou, when Thou didst turn Thine eyes upon the work of Thy hands, didst see that all was good; but man, when he turns to the work of his hands, sees that all is only vanity and vexation of spirit, and finds no rest. If, therefore, we water with our sweat the work of Thy hand, Thou wilt deign to make us partakers of Thy vision and Thy rest. Vouchsafe to fix in our hearts those feelings so worthy of Thee, and to impart to the human family new benefits, by our hands, and by the hands of those whom Thou shalt inspire with like sacred intentions."[1] Elsewhere he writes: "It is true that a little natural philosophy inclines men towards atheism, but a more profound philosophy brings them back to religion. For the human understanding, so long as it looks upon second causes separately, may stop at them, and not go beyond them; but when it rises to the contemplation of the close bond which brings them together and unites them, it is necessary for it to have recourse to Divine Providence."[2]

[1] "Instauratio Magno." Distribution de l'ouvrage.

[2] Verum est, parum philosophiæ naturalis homines inclinare in

Bacon's religious faith is unquestionable. What was the action of that faith upon the work of the savant? Science, in his view, is a rich treasure, consecrated to the alleviation of the lot of humanity, and to the glory of the Author of all things:—"The three steps by which science rises to unity are somewhat similar to that three-fold ascription, *Sanctus, sanctus, sanctus;* for God is holy in the multitude of His works, holy in the order in which He has disposed them, and holy in their harmony."[1] This passage indicates a disposition of mind similar to that which habitually animated Kepler. In Bacon it is but a passing gleam; it even happens to him, in what concerns the idea of order and harmony, to express himself in a sense contrary to the words just quoted; but what was his essential work? He proclaimed, in opposition to the spirit of system, the necessity of observation; and he did this with an extraordinary *éclat,* which constitutes the most solid part of his glory. Let us see how he expresses himself upon this subject. I quote the notice prefixed to his "Natural and Experimental History":—

"It is impossible to urge on men too strongly, and entreat them in their own interest, to subordinate their mind to the attentive observation of things. . . . A

atheismum; at altiorem scientiam eos ad religionem circumagere. Etenim intellectus humanus, dum causas secundas intuetur sparsas, interdum iis acquiescere possit, nec alterius penetrare; verum quum tandem catenam earum, connexarum inter se, et confœderatarum, contemplari pergat, necesse habet confugere ad providentiam et deitatem ("Sermones Fideles," xvi.). Bacon has also expressed his thought in these words so often quoted: "Philosophia obiter libata a Deo abducit, pleniter hausta ad Deum reducit."

[1] "De Dignitate et Augmentis Scientiarum," livre iii. chap. iv.

multitude of systems and sects may appear in all ages, and the exuberance of such growths is really inexhaustible. One fancy gets hold of this man, and another finds favour with that: a clear and calm day has not yet risen upon things. Each man looking upon the universe from the recesses of his own brain, as from the recesses of Plato's cavern, builds his own system. . . . Might we not say that we are expiating the sin of our first parents, without being, any the more for that, reclaimed from the temptation to fall into it ourselves? They tried to be equal with God; their posterity pretend to more, for we create worlds, we command nature, we lord it over it; we would have everything according to the paltry views of our presumption, not according to the Divine wisdom, or the laws of even the nature of things. I do not know which we wrest and torture most, things or minds; for, without inquiring at all for the signs which may reveal to us the stamp of God, we begin by impressing that of our own image upon His creatures and His works. It is not, therefore, without grounds that we lose our empire over the creatures; and, though after the fall of man there was left to him some power over the untractable creatures, to subdue and direct them by true and solid means, our imprudence causes us to lose that faculty, because we would raise ourselves to the level of deity, and abandon ourselves to the tracks of our own reason.

"If we are sensible of any humility before the Creator; if we experience that feeling of veneration which proclaims within us the glory of His works; if in our hearts there remains any love for our fellows, enough of

self-devotion to make us desire to supply the wants and solace the miseries of humanity; if we are sufficiently possessed with the love of truth to search into the sense of things; if our minds no less have horror of darkness, and we are animated with the desire to purify the human understanding,—we must be continually advising men to reject in part, or at least to put aside those absurd and frivolous systems which have audaciously formulated theses where there was no room but for hypotheses, which have placed fetters upon experiment, and impertinently set themselves above the works of God. It is humbly, with a sense of reverential fear, and after having, in a manner, purified themselves from every preconceived idea, that men must approach the grand book of creation and unroll its pages; regard it in long contemplation, meditate upon it, and religiously impress themselves with it."

The meaning of these words is clear. The power of the Creator being a free power, we can never find in our reason the necessary origin of things. When we substitute for the observation of facts systems the produce of our own understanding, we misconceive altogether the nature of the Divine work. To observe is to adore; to pretend to construct a world of fancy, instead of ascertaining the real work of infinite power, is the folly of pride; humility in the presence of God is the key of science. Everybody knows that Bacon was the great apostle of the rights of observation and experiment; few people know that it was from the contemplation of the power of the Creator, as opposed to the pretensions of the systematic spirit, that he

derived his grand rule of method, strengthening by the influence of his faith the natural tendency of men's common-sense. His capital error was his believing that experience by itself could reveal truth to us, and his confounding preconceived systems, which must be got rid of, with the guiding principles without which thought would remain stationary.

We come now to the principal founder of modern physics,—the man who determined the real object of science, which Bacon failed to recognise. From what source did Descartes derive his ideas?

Descartes.

Descartes was a genius essentially mathematical; still, when he definitely formed the project of consecrating his life to the reform of science, he did it with a pious feeling, and in answer to an inner appeal which he regarded as a manifestation of the Divine will.[1] His life offers none of those contrasts which throw a shade over the memory of Bacon. Worldly honours, social enjoyments, the care of his fortune, the joys even of family life,—he sacrificed all to the requirements of an austere and continued study. The religious feeling which had animated him during his life displayed itself in a striking manner at the time of his death. He was seized with a singular kind of delirium, which took from him the perception of things present to him, without disturbing at all the exercise of his intellectual faculties. "During all this time," says his biographer,

[1] Voir Baillet, "La Vie de M. Descartes," tome i. page 81, et suivantes, et p. 120.

"those who approached him remarked a peculiarity singular enough in a man whom many believed to have had his head filled all his life with nothing but philosophy and mathematics; and this was, that all his wanderings of mind ran in a pious strain, and had reference only to the greatness of God and the miseries of man."[1] The religious sentiments of Descartes, like those of Bacon, are manifested in his scientific writings. In his third "Méditation" he has just established the proof of the existence of the perfect Being, and he stops in the series of his deductions to express himself as follows:—"But before I examine this more carefully, and pass to the consideration of the other truths which may be gathered from it, it seems to me to be only right to pause for a while in contemplation of that God all-perfect, to ponder deliberately His marvellous attributes, to consider, admire, and adore the matchless beauty of that immense light, at least so far as the powers of my mind, which remain in a manner dazzled by it, shall permit me to do so. For, as faith instructs us that the sovereign felicity of the future life consists only in that contemplation of the Divine Majesty, so we find by experience even now that a like meditation, though beyond all comparison less perfect, causes us to enjoy the highest satisfaction which we are capable of experiencing in this life."

Descartes committed grave and numerous errors in the construction of his system. Almost all these errors are due to the fact that he did not realise the necessity of observation proclaimed by Bacon. The fact is

[1] Baillet, tome ii. page 419.

extraordinary, since he had affirmed, without reserves or limitations, the dogma of the Divine liberty. This failure of agreement between his metaphysical theory and his method is a question in the history of philosophy which we have not to discuss here. Beneath the errors of his systematic construction, as we have seen in the preceding essay, he laid the foundations of modern physics, as they subsist at this day. In the chains which unite human thoughts there is not a closer link than that which connects his great discoveries with his faith in God. The proofs of this superabound, and I must confine myself to choosing a few of them.

Descartes affirmed, as strongly as any one, and more strongly, the rational character of the universe; that is to say, the agreement of the laws of nature with the laws of our thought. His error, whence proceeds the fault of method which has just been pointed out, is to have overlooked the hypothetical nature of our theories, and the control of experience to which they must be submitted. From the idea that nature is intelligible to us, he passed to the very different idea that reason alone can construct the system of the universe. But on what foundation rests his conviction that the universe is intelligible to us? The reason has a natural confidence in itself, and to believe in the reason is to believe in the agreement of thought with reality: but this natural confidence may be shaken: scepticism is the historical manifestation of this disturbance. Descartes set forth the arguments for scepticism in all their force. On what basis does he place the understanding to secure it from the assaults of doubt? On

that of faith in the Divine veracity. "It seems to me," he says, "that I discover a road which will lead us from the contemplation of the true God, in whom are hid all the treasures of wisdom and knowledge, to acquaintance with the other things of the universe. For, first of all, I am persuaded that it is impossible that He should ever deceive me, since in all fraud and deceit is found some kind of imperfection, and although it may seem that to be able to deceive is a mark of subtlety or power, yet to be willing to deceive is a proof, no doubt, of weakness or malice, and consequently cannot be met with in God. Again, I know by my own experience that there is in me a certain faculty of judging, or discerning the true from the false, which I have doubtless received from God, as well as all other things which are in me, and which I possess; and since it is impossible that He should wish to deceive me, it is also certain that He has not given it to me such that I can ever fail when I use it as I ought."[1] When our mind holds fast, not by our prejudices, our vain imaginations, our combinations of ideas which may always be false, but by the primitive elements of the understanding, we are in presence of God's work; and hence this great Cartesian rule, that *our clear and distinct conceptions are true.* Bacon made the necessity of observation to rest upon the idea of the Divine power, in presence of which we must humble ourselves; Descartes makes confidence in our reason to rest upon the idea of the Divine goodness, to which we must trust ourselves. It is one of the points of doctrine upon

[1] "Méditation Quatrième."

which he explains himself with the most entire lucidity, "That very consideration which I have taken as a rule, namely, that the things which we conceive very clearly and very distinctly are true, is certain only because God is, and because he is a perfect Being, and because all that is in us comes from Him. . . . If we did not know that all that is in us of real and true comes from a perfect and infinite Being, however clear and distinct our ideas might be, we should have no reason for being sure that they had the perfection of being true."[1] And elsewhere: "The certainty and truth of all science depends wholly and only upon the knowledge of the true God."[2] Faith is the support of the reason, and reason, strong by this support, may endeavour to comprehend nature.

This world, which is governed by laws conformable to those of our understanding, is one, since it is the work of one sole Creator, and this unity is the principle of its harmony.

What is the nature of the phenomena of the physical world? If we separate material phenomena from the sensations which they cause us to experience, they are reduced to a pure mechanism. This thought, commonly accepted now, was in its origin a conception of extreme boldness, which could not take its place in the domain of science until after an ardent and prolonged struggle. What, in the mind of Descartes, was the basis of a theory so novel and so daring? It was at first the distinction clearly established between the external

[1] "Discours de la Méthode," fourth part.
[2] "Méditation Cinquième," at the end.

phenomena which are revealed to us by the corporeal senses and the psychical phenomena which are only manifested to the internal sense. We must not attribute to the body, the object of our sensible perceptions, any of the properties of the soul. Now, if we take away from our conception of the body all the properties which suppose a relation between material facts and the mind, such as the sensations of light, heat, colour, sound, nothing remains conceivable to us in matter but mechanism. If, therefore, the material universe is intelligible to us, the explanation of these phenomena must be found in what we are able to conceive. But who or what warrants us that the world is intelligible to us, or that science is possible? Faith in God, which justifies and strengthens our natural confidence in the reason. Thus it is that the thoughts of Descartes flow in a logical chain, and therefore his work, the "Principes de la Philosophie," of which the object is physics, opens with prolegomena exclusively devoted to establishing the distinction between the soul and the body, and the existence of God. These prolegomena are in an immediate relation with the reformation of science of which Descartes was the principal agent: our present physicists, as soon as they rise to theories a little general, always suppose them, often without being aware of it.

All explanations of physics having to be sought in mechanics, the laws of motion become the fundamental basis of science. Descartes establishes two principal laws: the law of inertia, which is found in the treatises of the time on mechanics in the very terms in which he

formulated it; and the law of the constancy of force, which has required modification in its expression, but which, as to its essential substance, has remained as he had established it. Here are truths known for two hundred years past, which are wrongly taken for modern discoveries, because they had for a time disappeared from the grand current of science, to reappear in our days with new *éclat*.

The law of inertia, in so far as it affirms that an inanimate body does not pass of itself from the state of rest to that of motion, is conformable to appearances, and there is no question to propose on the subject of its origin: but the affirmation that a body once in motion would continue to move indefinitely with the same velocity is a very bold affirmation, quite contrary to the immediate data of experience. What was its origin in the mind of Descartes? It was this: God is the first cause of motion, and God, by virtue of His perfection, acts in a manner which does not change, so that we must admit that the universal motive power, which is the expression of His will, remains constant.[1] On the same idea rests the affirmation that every body which moves tends to continue its motion in a straight line. "This rule, like the preceding, depends upon the truth that God is unchangeable, and that He preserves motion in matter by a very simple operation: for He does not continue it as it might have been some time before, but as it is precisely at the very instant when He continues it."[2] "Now, of all motions that in a straight line is the only one which is entirely simple;

[1] "Principes," partie ii. § 36.   [2] *Ibid.* § 39.

and the whole nature of which is understood in an instant."[1] Descartes does not dispute that these rules seem contrary to sensible experience; but he still believes that he must propound them: "for what more firm and more solid foundation," he asks, "could be found on which to establish any truth, than the very firmness and immutability which are in God?"[2] We have here a very clear proof of the bond which connects the bases of physics with religious conceptions; and this is why Descartes reckons that "atheists are in general more arrogant than learned or judicious;" and he attributes the intellectual malady from which they suffer to the fact that "many, desiring to be reputed as very clever, study nothing else than how to combat with arrogance the most evident truths."[3] It is impossible to deny that the grand theories of Descartes, in their true and durable parts, were, in his mind, the immediate consequence of his faith in God: to wish to trace them to any other source would be an attempt condemned by the abundance and very clear purport of the passages in which he has set forth his views.[4] He has sometimes been reproached, by those who have brought this fact under notice, with introducing religious sentiment into the construction of a science which must rest solely on the basis of observation. The reproach appears a

[1] "Le Monde," chap. vii. [2] *Ibid.*

[3] Epistle prefixed to the "Méditations."

[4] It appears to me that M. Liard, in his very valuable work upon Descartes (1 vol. 8vo, 1882), has not distinguished, as it is advisable to do, between that philosopher's metaphysical construction and his idea of God,—an idea which is the common foundation of his method, his physics, and all his philosophy.

strange one when we have come to know that the observations which have given validity to the bases of modern physics are the experimental confirmation of theories which could not have had their origin from experience. If the mind of Descartes, that of Copernicus, and that of Newton, had been purged from that religious element which some of our contemporaries find fault with, we should still have had to do, perhaps, in astronomy with the system of Ptolemy, and in physics with the doctrine of substantial forms.

Galileo.

Descartes was the most powerful of the initiators of modern science; but the very audacity of his thought, and the vice of his method, led him into great errors. Galileo was wiser. He drew out the rules for the true method for the study of natural phenomena, by pointing out that we discover laws by means of hypotheses which must continually be placed under the control of experience. What is the principle which must direct the mind in the choice of hypotheses? Here is the answer of Galileo: "The laws of nature are the simplest that can be. . . . If we raise our thoughts, therefore, to *the most perfect and the simplest rule,* we shall form the most probable of hypotheses. We may follow the consequences of them with curious interest, and the mathematics may without scruple transform them into elegant theorems: we risk nothing. Geometry has already studied many curves unknown in nature, and the properties of which are no less admirable: it is to

geometry alone that our results will appertain if experiment do not confirm them."[1] It is the argument of the simplicity of the laws of nature which leads Galileo to accept the doctrine of Copernicus,—the doctrine which was to have so great an influence upon his future. One of the parties in the "Dialogue sur les Systèmes du Monde" expresses the mind of the author by pointing out that "the multiplicity and confusion of the means by which the results would be produced in the system of Ptolemy would of necessity lead to the rejection of a great many axioms generally admitted in philosophical science: for instance, that nature does not multiply things without necessity, and that she employs the easiest and simplest methods of producing her effects; that she does nothing in vain, and the like. He regards the explanations, so simple and easy, of the system of Copernicus as the most marvellous speculation of the human intellect."[2]

What are we to understand by that nature which employs the simplest means? No doubt in this respect is possible. For Galileo that nature, of which the intelligence is wonderful, is the wise and mighty Creator. He holds the opinion that his adversaries—those who condemned his doctrines as impious—opposed the decrees of a mistaken theology to the natural consequences of a well-grounded faith in God. In his defence, addressed to the Grand-Duchess Christine, he says:—

[1] Galilée et ses Travaux, dans les "Fondateurs de l'Astronomie Moderne," par Joseph Bertrand.

[2] "Galilée," par le docteur Max Parchappe, p. 383.

"To interdict all astronomical science—what would this be but to condemn a hundred passages of Holy Scripture, which teach us how the glory and greatness of the Almighty God are marvellously revealed in all the creation, and divinely read in the open book of the heavens? And let it not be thought that the reading of the grand thoughts written upon these pages stops at the contemplation of the splendour of the sun and stars, their rising and their setting—this is the term beyond which the regards of animals and of the vulgar cannot penetrate. But we have here mysteries so profound, conceptions so sublime, that the watches and labours of the most subtile geniuses by hundreds have not been able to penetrate them entirely, notwithstanding continued investigations during thousands of years. The ignorant must be taught this. Just as what the eyes take into their view in the external aspect of the human body is very little in comparison with the admirable contrivances which a clever anatomist and a philosopher can discover in it, when they inquire into the use of so many muscles, tendons, nerves, and bones; when they examine the action of the heart and the other principal organs; when they search out the seat of the vital faculties, observe the marvellous structure of the organs of the senses, and contemplate, without becoming weary of admiring and questioning, the receptacle of the imagination, the memory, the intellect—so, in the same way, that which comes merely under the sense of sight is nothing, so to speak, in comparison with the profound marvels which, at the cost of

long and careful observations, the genius of men of science is able to discover in the heavens."[1]

Galileo, bold innovator as he is, maintains at the basis of his labours religious thought wisely interpreted; and we see, in the passage above quoted, that he reckons that the progress of astronomy is calculated to increase the sentiment of adoration for the Creator of the worlds. It is the same thought which Charles Bonnet expresses in his "Contemplation de la Nature,"[2] when he writes: "*The heavens declare the glory of the Creator; and the expanse*[3] *makes known the work of His hands.* The sublime genius, who expressed himself thus nobly, was ignorant the while that the stars on which he was gazing were suns. He was before his time, and commenced the first majestic hymn, which future ages were to follow him in singing to the praise of the Master of the worlds." If the name of Galileo recalls one of the chief conflicts of science with theology, it must recall also, to those who have studied his works, the influence exerted on the progress of astronomy by faith in the wisdom of the Creator. The confusion set up between the doctrines of theology and the fundamental verities of religion seriously vitiates the polemics into which it is introduced.

Newton.

Newton has a double part in the history of science. He caused to be effected immense progress in astronomy and certain parts of physics; on the other hand,

[1] "Parchappe," page 137. [2] Partie i. chap. iv.
[3] Fr. *l'étendue.*

a little by his own fault, and still more by the want of intelligence on the part of his disciples, in substituting the theory of emission for that of luminous undulations, and in denying the Cartesian principle of the constancy of force, he brought about a recoil in the general science of nature. This fact has been established in our preceding study: we have here to consider especially the grand discovery which has cast most lustre on his name,—that of universal gravitation. This discovery excited an immense enthusiasm, and seems to have produced a religious impression even upon the mind of Voltaire. The following are verses from his "Lettre à Emilie sur la Physique de Newton":—

"God speaks, and at His voice confusion ends;
All, in all worlds, to one sole centre tends:
This spring, so mighty, Nature's soul, concealed
Till now in night, its working has revealed;
For Newton's compass sweeps immensities,
Lifts the great veil, and opens all the skies!

. . . . . .

Such things how beautiful! The soul refined
Rejoices in the truths by man divined;
And, far from trammels of this mortal clod,
Enraptured, seems to hear the voice of God."[1]

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[1] "Dieu parle, et le chaos se dissipe à sa voix.
Vers un centre commun tout gravite à la fois.
Ce ressort si puissant, l'âme de la nature,
Etait enseveli dans une nuit obscure.
Le compas de Newton, mesurant l'univers
Lève enfin ce grand voile, et les cieux sont ouverts.

. . . . . .

As for Newton himself, he was urged by the strength of his feeling to make profession of his faith, not only as a man in the private relations of life, but as a philosopher, and in the works which have established his fame. In concluding his "Principia," in which he has established the true system of the celestial motions, he expresses himself thus:—"The Master of the heavens governs all things, not as being the soul of the world, but as being the Sovereign of the universe. It is because of His sovereignty that we call Him the Sovereign God. He rules all things, those which are and those which may be. He is the One God and the same God, everywhere and always. We admire Him for His perfections, we revere and adore Him for His sovereignty. A God without sovereignty, without providence, and without object in His works would be only destiny or nature. Now, from a blind metaphysical necessity, everywhere and always the same, could arise no variety. All that diversity of created things according to places and times, (which constitutes the order and life of the universe), could not have been produced except by the thought and will of a Being who is *the Being*, existing by Himself, and necessarily."

The science, therefore, of Newton confirmed his faith; he took care to say this with so much emphasis, that no one has the least excuse for doubting it; but the science which confirmed his faith took its origin under

Que ces objets sont beaux! Que notre âme épurée
Vole à ces vérités dont elle est éclairée!
Oui, dans le sein de Dieu, loin de ce corps mortel.
L'esprit semble écouter la voix de l'Eternel."

the impulse of that faith itself. He effected a great step forward in science when he explained by a single law the three astronomical laws discovered by Kepler. This was to realise important progress in the road to unity and simplicity. Why did he seek for unity and simplicity? In order to observe "the rules which must be followed in the study of physics."[1] Newton, in fact, following in the steps of Galileo, and reconciling in a happy harmony the divergent views of Bacon and Descartes on the subject of method, will have all our theories to be submitted to the control of experience; but he knows that *à priori* rules must direct the choice of the hypotheses to be controlled. The first of these rules is the principle of simplicity. Whence does he receive it? From a tendency natural, no doubt, to the reason, but a tendency sustained and strengthened by the thought of the only and sovereignly wise God. It is Newton himself who tells us this. "Is it not," he used to say, "a proof that we are approaching to God when we arrive at laws more simple and more general?"[2]

[1] These rules are stated at the beginning of Book iii. of the "Principia."

[2] "Isaac Newton," par J. L. M., page 24. A professor of New York, M. Draper, published, in 1875, a volume upon "The Conflicts of Science with Religion." This volume contains the following assertions: "Newton demonstrates that the solar system is governed by mathematical necessity" (page 164). "The theory of Newton proves that the sun not only is, but must be the centre of our system; that the laws of Kepler are not only a fact, but the product of mathematical necessity, and that it is impossible they should be other than they are" (page 171). Mr. Draper reckons, therefore, that Newton demonstrated theses which are directly the contrary of what Newton affirmed in precise terms.

Leibnitz.

Leibnitz, whose encyclopædic genius left its traces in so many different directions, was in physics the greatest of the Cartesians: he continued Descartes by correcting him. His name does not remain connected with very striking discoveries of detail, but he exercised considerable influence upon the progress of science by his general ideas and his mathematical discoveries. His religious belief is indisputable. Two volumes of fragments of his works were compiled formerly, in which he refutes atheism, and lays the foundations not only of theism but of Christian beliefs; and since that time several of his works have been published which had remained unedited, and which supply fresh documents for a collection of that kind.[1] In his work, as in that of Descartes, the relation between the guiding principles and their common centre, the idea of God, is very manifest. He says that his idea of the differential calculus was derived from "the most profound philosophical source."[2] We have the right, therefore, to suppose that there exists a direct relation between his conception of the Divine nature ("the most profound philosophical source" cannot be otherwise understood) and his great mathematical discovery. This, however, is a point of history about which I do not feel that I have a right to express an opinion, the rather that

[1] In particular: "Système Religieux de Leibnitz," un vol. in-12. Paris, 1846.

[2] "Fortasse non inutile erit ut nonnihil in præfatione operis tui attingas de nostrâ hâc analysi infiniti, ex intimo philosophiæ fonte derivatâ."—Lettre à Fardella, publiée par Foucher de Careil dans les "Nouvelles Lettres et Opuscules Inédits de Leibnitz," page 327.

it would be necessary, before doing so, to make a comparative study of Newton's infinitesimal calculus. In what concerns physics, the centre of the thought of Leibnitz is the harmony established by God between all the elements of the universe. He conceives the organisation of the world as it now is to be the result of a development, continued and progressive, of the creative plan, a development effected by the realisation of the virtuality[1] proper to created things. This conception acts directly upon his scientific theories. He employs it in particular to establish the conservation of force. This may be shown, as well in his letters to Bourget,[2] as in the following passage from his treatise on the "*Principes de la Nature et de la Grâce*": "The supreme wisdom of God caused Him to choose, above all, laws of motion the best adjusted, and the most suitable to abstract reasoning or metaphysics. He keeps up in them the same quantity of total and absolute force, or of action; the same quantity of respective force, or reaction; the same quantity, in short, of directive force. Moreover, action is always equal to reaction, and the entire effect is always equivalent to the full cause. It is surprising that from the sole consideration of efficient causes, or of matter, we could not give account of those laws of motion discovered in our time, and a part of which have been discovered by myself. For I have found that in reference to them recourse must be had

[1] "In one grain of corn there lieth dormant a virtuality of many other, and from thence sometimes proceed an hundred ears."—Brown's Vulg. Err. [Tr.].

[2] Edition Dutens, tome ii. partie i. page 335.

to final causes, and that those laws do not depend, as logical, arithmetical, and geometrical truths do, upon the principle of necessity, but upon the principle of suitableness; that is to say, upon the choice of wisdom. And this is one of the most satisfactory and tangible proofs of the existence of God, for those who are competent to fathom these things."[1] The proof of the existence of God indicated in these words is the result of a circle which shuts upon itself; thought, through the medium of science, comes to confirm the idea of the supreme wisdom which was its point of departure.

The weak side of Leibnitz is his theory of liberty. One sees, at the same time, in his "Théodicée," the general tendency of his thought, and the serious gap which it contains. There did not occur to him the conception that the harmony of the domain of morals is conditional. He wished to extend to the entire universe the conception of the fixed harmony of nature; and so he makes vain efforts to find room in his system for the fact of human responsibility. This is, however, the general character of the philosophy of the seventeenth century, the essential work of which, from a scientific point of view, was accomplished in the domain of the mathematical and physical sciences. In this domain all the labour of the mind is penetrated and directed by belief in the unity of God, of God sovereignly wise—that great acquisition which the Middle Ages, possessed of it through Christian preaching, had bequeathed to the modern world. On this subject I have only given some hasty references; but it will be easy

[1] Edition Erdmann, page 716.

for those who like to take the trouble, by reading the writings of the founders of science, to collect abundant proofs in support of my affirmation.

We are come, with Leibnitz and Newton, to the end of the period which is properly that of the founders. All, without exception, have found in their belief in God—one, mighty, and wise—the confirmation and the development of the natural tendencies of the reason. We are therefore warranted in saying, without ignoring in any measure the necessity of observation and experience—conditions indispensable to true theories—that their science was produced under the influence of their faith.

Laplace.

As we approach our own times we meet with an illustrious name, which might be opposed, apparently, to the general application of the foregoing considerations. This name is that of Laplace. Looking at science in general, Laplace occupies a position higher than which there are few or none; but he is not an initiator, a founder in the true sense of the term. As the end I have in view may cause me to be suspected of some partiality, I will leave it to men to speak on this subject who are not liable to such a suspicion. In his "Éloges Historiques," Fourier, permanent secretary to the Academy of Sciences, has characterised the genius of Laplace in these terms: "It cannot be said that it had been given to him to create a science entirely new, as did Archimedes and Galileo; to give to mathematical doctrines principles original and of

immense extent, as did Descartes and Leibnitz; or to be, like Newton, the first to transport to the heavens and to extend to all the universe the terrestrial dynamics of Galileo. But Laplace was born to perfect all, to fathom all, to put back all limits, to solve what would have been thought unsolvable. He would have completed the science of the heavens, if that science could be completed."

M. Barthélemy St.-Hilaire reproduces and confirms this judgment: "Laplace came to accomplish what Newton had begun. The "Méchanique Celeste" is a systematic and regular development of Newtonian principles; but he only sets forth, with all the resources of the most extensive and most exact analysis, the laws which another had revealed concerning the veritable system of the universe. It is a stupendous work; but what is new in it consists rather in the formulæ and demonstrations than in the ground-work and essence of things. It is the law of universal gravity followed under all its phases in the countless bodies which people space, and the chief of which are accessible to our observation and subject to our calculations. Laplace himself did not flatter himself that he had done more; but he brought to his work such a power and such a fecundity of analysis that, in demonstrating all, he seemed to produce all, although he confined himself to organising all and putting all in order." [1]

Laplace, then, is not an initiator—the author of a new direction of thought. In his "Mécanique Céleste," he is the continuer of Newton; in his nebulous theory

[1] Preface à la "Physique d'Aristote," page clvi.

he develops a germ created by the genius of Descartes. He follows the impulse which comes from those who have gone before him: he applies their principles as he has received them. He admits in particular, and proclaims again and again, the principle of simplicity, to which he appeals in support of the system of Copernicus, and which he gives as a basis for the law of inertia. If belief in the existence of a mighty and wise Creator is not expressed in his works, still it is there, in a manner mediate but very real, by the influence which it exerts there through the work of his predecessors which he carries on by developing it.

The position of Laplace with regard to the religious idea offers matter for an interesting study. "It seems," says he, "that nature has arranged everything in the heavens to make sure the continuance of the planetary system, with views similar to those which she appears to us to follow so admirably upon the earth for the preservation of individuals and for the perpetuation of species."[1] Here we have intelligent nature, who proposes to herself an object, and pursues it by means of admirable views. The author continues: "This sole consideration would explain the arrangement of this system, if the geometrician had not to extend his view farther, and to seek in the primordial laws of nature the cause of the phenomena most clearly pointed out by the order of the universe. . . . Newton affirms that *the admirable arrangement of the sun, planets, and*

[1] "Exposition du Système du Monde," a la fin, page 442 de la 4me edition.—This close of the work was altered in the following edition, the nebular hypothesis having passed from the text to a note.

comets can only be the work of a Being intelligent and almighty. . . . But may not this arrangement be itself an effect of the laws of motion; and may not the Supreme Intelligence, which Newton supposes, have made it to depend upon a more general phenomenon? Such is, according to us, that of a nebulous matter scattered in various masses through the immensity of the heavens."

This is a passage of the highest interest. The idea of the author is, that the existing order of the universe may be the result of the application of physical laws to the primitive nebulous matter; and he remarks that, in this case, the present order of things would result from general laws, and from the primordial diversity of the masses of matter. On this supposition, the work of the Supreme Intelligence would be as manifest in the primitive disposition of matter, and in the laws which govern it, as in the present state of things, since this present state would be virtually contained in the state supposed to be primitive. The physical antecedent of phenomena does not in fact replace the cause which produced them and the intelligence which arranged them. Laplace seems, therefore, to recognise the truth, too often overlooked, that efficient causes are of another order from final causes, and that, when all is said, Leibnitz is right when he seeks in final causes, that is to say, in the purposes of the Creator, the *raison d'être* of efficient causes. But this view of the truth, clear as it is, seems to become confused when, in the next page, the author says: "If we look through the history of the human mind and of its errors, we shall

find final causes constantly put back to the boundaries of its knowledge. . . . In the eyes of the philosopher they are merely the expression of the ignorance in which we find ourselves of the true causes." Laplace really seems here to fall into the very error from which he had just escaped, and to think that the study of physical causes may do away with all reference to final causes. To come back to my direct object, this savant has indeed been able in his works to dispense with the idea of the wisdom of the Creator, but he has followed the guiding principles of which this idea had been the source for Copernicus, Kepler, Galileo, and Newton. One may say, figuratively, that if the sun is absent from his work, yet that his work is visibly enlightened by the rays of the orb of day.

Let us pass to more modern times. By the side of men who develop and cultivate the germs of the past, we meet with minds especially gifted with the genius of discoveries—initiators. These men are placed under the influence of the same convictions which animated the founders, and these convictions furnished them with the same principles.

Ampère.

Ampère is one of the best types of the scientific genius. His laws, so beautiful and simple, of electro-magnetism, which will be, M. Littré thinks,[1] the foundation of his most lasting fame, are only a part of his vast labours. His religious faith, ardent in his youth,

[1] Notice placée en tête du 2me volume (posthume) de "L'Essai sur la Philosophie des Sciences de André-Marie Ampère."

then shaken during some years, became again firm and undisturbed at the period of his maturer age. "We have always seen him," says Ste.-Beuve, "unite and reconcile without effort, in a way to strike with astonishment and respect, science and faith."[1] The great verities of the spiritual order were for him not only objects of faith, but of scientific certainty. "The existence of the soul and of God," he used to say, "is an hypothesis, but it is a demonstrated hypothesis, as certain as those of Copernicus and Newton. Now, there is not, in whatever is not a matter of immediate intuition, any greater certainty than that which rests upon the evidence of a proved hypothesis."[2] This thought is easy to understand. A particular order of phenomena confirms a special theory; all spiritual phenomena justify the thesis of the existence of the soul; and science in its totality, which is but the progressive knowledge of the order of the universe, witnesses in favour of the existence of the Supreme Ordainer. Laplace in his works confined himself to following the current of science established by his predecessors: Ampère goes back to the source, as had done Descartes, Newton, and Leibnitz. To his religious faith he joined an ardent love for metaphysical researches—a love satisfied and maintained by his friendly relations with Maine de Biran. The religious and philosophical tendency of his thoughts was the guiding principle of his labours as of his life.

[1] "Portraits Littéraires," tome i.

[2] "La Philosophie des deux Ampère," publiés par Barthélemy St. Hilaire, page 155.

Liebig.

Liebig raises reflections of the same kind as those which concern Ampère. M. Moleschott, who combats his doctrines by opposing to them a naked materialism, considers him "the greatest chemist of Germany." In order to controvert him he is forced to acknowledge that the greatest chemist of Germany was possessed by a conviction, which led him to write such words as these: "The simple experimental knowledge of nature imposes on us, with force irresistible, the conviction that that something (the human mind) is not the limit beyond which there exists nothing more which resembles it, or which is more perfect than it. Our perception only reaches to inferior degrees. This truth, like all others in the physical sciences, establishes the existence of a superior Being, of whom our senses can give neither the idea nor the knowledge, and of whom the perfecting of the instruments of our mind can alone enable us to conceive in His greatness and sublimity."[1]

Leibig does not consider his religious belief and his scientific labours as two facts simply juxtaposed; he reckons that religious thought guides science in the way of truth, and preserves it from false steps. He brings this thought into full view in a personal confession. He believed he had discovered an application of chemistry to agriculture, the effect of which would be to furnish a remedy to the exhaustion of the soil. His discovery turned out to be false; and a more attentive

[1] Liebig, "Lettres sur la Chimie (en Allemand)," page 31. Molleschott, "La Circulation de la Vie," lettre i.

study of his subject led him to ascertain that the object which he was pursuing was actually realised in a way of which he had had no suspicion. The following is his own account of this, published in 1862: "After having submitted all the facts to a new and very searching examination, I discovered the cause of my error. I had sinned against the wisdom of the Creator, and I had received my just punishment. I was wishing to perfect His work, and, in my blindness, I thought that in the admirable chain of laws which preside over life at the surface of the earth, and maintain it ever in freshness, there was wanting a link which I, feeble and impotent worm, was to supply. Provision had already been made for this, but in a way so wonderful that the possibility of such a law had not so much as dawned upon the human understanding."[1] This is to say, in plain terms, that in the opinion of the greatest chemist of Germany, doubt about the wisdom of the Creator may be the occasion of a mistake even in the study of agricultural chemistry.

Fresnel.

The labours of Fresnel upon the nature of light having been one of the starting-points of the contemporary renovation of physics, it is interesting to know under what influences he was led to the theory which has rendered his name illustrious. His "Mémoire sur la Diffraction de la Lumière," presented to the Institute in 1818, commences with an introduction, in

[1] "Chemistry applied to Agriculture and to Physiology" (in German). Seventh edition, page 69.

which he gives an account of the progress of his thought. He points out the existence of two systems upon the nature of light—that of emission supported by the great authority of Newton, and that of the vibrations of a fluid, which is connected through the medium of Euler, Huyghens, and Hooke, with the labours of Descartes. Fresnel adopts the latter system. Why? Because nature's plan is to do much with little—to produce the maximum of effects with the minimum of causes; and because the system of undulations furnishes more simple explanations than that of emission. He develops this thesis at length, and adds, but only as a secondary argument, that the system of undulations accounts for certain phenomena of the diffraction of light, which the system of emission does not account for. Any one may assure himself by consulting the text of Fresnel that it is the principle of simplicity which has directed his thought, and has been the origin of his theory.[1] But what did he understand by this nature whose plan is to effect much with little? His thoughts in this respect are not doubtful. Verdet affords us on this head the following information: Fresnel was brought up by a Jansenist mother, and educated by the writers of Port-Royal. His religious opinions were modified by the influences amidst which he was placed, and by his scientific culture. His faith in a supernatural revelation was shaken, but (and this is all that concerns the subject of my study) "the existence of God, Providence, the liberty and immortality of the human soul, the great spiritualist doctrines on which

[1] See "La Logique de l'Hypothèse," pages 152-155.

those precious truths appeared to him to depend, were become the constant subject of his thoughts, and he had hoped that by dint of labour and meditation he should give to his convictions that rigorous exactness which commands universal assent."[1] Such was Fresnel's belief. This belief gives validity for him to the principle of simplicity, and research for the simplicity of the laws of nature is the essential factor of his discovery.

Faraday.

Faraday was a fervent Christian, the member of a religious communion separated from the Anglican Church. He was an elder of his church, and only gave up preaching at the time when he had to relinquish the teaching of science. "The name of Faraday therefore must be added to the list of those who have been as sincere in their faith "as profound in their science."[2] Seeing the unity of physical forces manifested more and more as the result of a series of labours, in which his own work occupies an important place, he conceives the hope of discovering the relations of attraction with the phenomena of general physics. He writes: "Magnetism, a few years ago, was still only an occult force affecting merely a very small number of bodies. We now know that it influences all bodies, and has the most intimate relations with electricity, heat, chemical action, crystallisation, and, through crystallisation, with all the forces brought into play in cohesion. In this

1 "Notice sur Verdet," par A. De la Rive, page 16.
2 "Eloge Historiquè de Michael Faraday."

actual state of things, we feel strongly urged to continue our researches, encouraged by the hope of discovering the link which connects magnetism with gravity."[1]

Robert Mayer.

The labours of Robert Mayer relative to the conservation of energy have exercised a considerable influence upon the reconstitution of the bases of physics. Robert Mayer expounded his general views upon the theory of heat to the Scientific Congress at Innspruck in 1869. He applied himself to trace the line of demarcation which separates spiritual phenomena from physical actions, in words quoted in my first study; and he went on to remark that the possibility of science has for condition the agreement between the laws of reason and the phenomena. "Without this eternal harmony, established by God between the world subjective and the world objective, all our thoughts would be barren and unproductive."[2] Relying on this principle, he admits as a primitive law the indestructible character of force —a principle which is visibly for him the result of the constant action of the universal motive power. The three bases, on which the thought of this savant is supported, are therefore—the immateriality of the soul, the rational character of the phenomena, and the supreme unity which makes both the harmony of nature, and the harmony of nature and of the human mind. These are the bases of thought of the founders of the science of the

[1] "Faraday, Inventeur," par John Tyndall, page 85.

[2] *Revue des Cours Scientifiques* du 22nd Janvier, 1870.

seventeenth century, and very especially of Descartes. We find them again, without any variation, in one of the principal initiators of contemporary science. Robert Mayer has less established the constancy of force as an induction drawn from experience than he has sought in experience the proofs of his theory. We read in the preface to the volume in which M. Cazin treats of the theory of heat,[1] "The form of reasoning adopted by several authors who have written upon the mechanical theory of heat might lead one to think that they belong to some philosophical school, and that they have found in certain metaphysical doctrines the principles of which they make use. Now, nothing is farther from the fact than such an opinion. When they say that the phenomena of heat are due to certain motions of matter, physicists simply express a fact of experience, about which there can be no doubt, and they do not all pretend to draw from the correlation which they observe between heat and the sensible or atomic motion of bodies any consequence relative to the constitution of the universe." The author appears to me in this passage to confound two distinct things—what physicists would do if they rigorously followed the method of empiricism, and what in reality some of the savants who have founded the mechanical theory of heat, and especially Robert Mayer, have done. Not only are the doctrines of the conservation of force and the transformation of motions rich in consequences for the theory of the constitution of the universe, but they have been produced historically by

[1] "La Chaleur," par Achille Cazin, Professeur de Physique au Lycée de Versailles, 1 vol. in 12, Paris, 1867.

a definite conception of the principle of the universe—a conception which has directed thought in the choice of hypotheses which experience has confirmed.

In quoting the foregoing names, I have not, in the interests of my cause, made an arbitrary choice among savants. The reader may easily assure himself that those whom I have taken as examples are, in the general opinion, the founders of modern science, and the principal initiators of its development in our own time. I am far, besides, from having made use of all the resources which history supplies to me, for, not to speak of several others, I have not mentioned either Sir David Brewster or Volta, who, to high scientific eminence, joined positive religious convictions.

The direct proof of my thesis is now completed. In the foundation and development of physics, definite principles have directed experimental researches, and belief in God has afforded to those principles a solid point of support. This belief has strengthened and confirmed the tendencies of the reason which lead it to the research for unity, harmony, and simplicity. Scientific hypotheses, although conceived under the influence of true principles, still have no value, except so far as they are confirmed by experience; for the human mind is prone to wander, even when it takes truth as its point of departure. In the intellectual locomotive, experience is the combustible, and belief—the centre of the guiding principles—is the fire. This Kant acknowledged and proclaimed, when he wrote: "For the unity which reason gives me as a guiding clue in the investigation of nature, I know no other condition than

to suppose that a Supreme Intelligence has ordered all in pursuit of the wisest ends. To suppose a wise Author of the universe is therefore a condition of an end, which, in truth, is contingent, but which is, however, not without importance—that, namely, of having a guiding clue in the investigation of nature."[1]

The action of principles upon experimental researches, the action of the idea of God upon principles, such is the historical fact.

There exists a certain number of savants making profession of doctrines the tendency of which is positively atheistic; but, from the point of view of scientific discoveries, these are not men of the highest order of genius; they are neither founders nor initiators. We may clearly observe a marked difference between minds which dominate their science and those which are dominated by it. A mathematician, for example, who knows his formulæ well, but who has never reflected upon their origin, may lose himself in a mechanical materialism; but the inventors, such as Descartes, Leibnitz, and Newton, behold in the mathematical sciences the pure laws of the understanding, and they see in those laws the radiation of the Supreme Intelligence. A physiologist totally absorbed by the operations of the scalpel and the microscope, may ignore the reality of psychical facts; a naturalist, buried in the exclusive observation of the animal series, runs the risk of forgetting the distinctive elements of human nature; but a man of the power of Linnæus, or of the stature of

[1] "Critique de la Raison Pure," tome ii. page 384 de la Traduction Barni.

Haller will not allow himself to be so engrossed by a single one of the elements of the universe as to forget the rest. As to the physical sciences, which have formed the special object of my study, there is not a single one of their founders or of their great initiators who has not been placed under the influence of the idea of a mighty and wise Creator, and who has not received from that lofty contemplation, the rays of light which have directed his steps. We must never presume rashly to forecast the future; but such has been the fact up to the present day.

And would this fact be accidental? The union of faith and science in the men whom I have passed in review — was it only a fortuitous juxtaposition? Assuredly not. It is perfectly well established that the work of the founders was placed under the direct influence of philosophical elements contained in their religious belief. Would this belief have had only a provisional value? May it be compared to a scaffolding useful for commencing the construction of a building, but which is afterwards of no further use? Not so; and this will be manifest as we proceed to consider the consequences of negation, or of the suppression of the idea of God. This will be the counter-proof or the indirect proof of my thesis.

Consequences of Scientific Atheism.

By *scientific* atheism I mean the suppression of the idea of the Creator in the study of nature. This suppression does not allow us to infer the atheism of

the savant, who may have, as an individual, personal beliefs. Scientific atheism followed in its consequences is a principle destructive of science. This is what at the beginning I called the question of principle, the study of which naturally comes after that of the question of fact.

In order well to understand the following considerations, we must distinguish three classes of savants: the first consists of those who have a firm belief in the unity, power, and wisdom of the Creator, a belief which strengthens their reason in the application of the guiding principles of their researches. We may say of them all what M. Tyndall says of Faraday: "A vein of pure philosophy circulates in their writings."[1] All the founders and great initiators without exception belong to this category. The second class is composed of men who follow the current of science as it exists, without tracing it back to guiding principles, or at least without having a clear view of the bond which connects them with a supreme conception. These men are very numerous: they form the *people* of the savants: they are not placed under the immediate and constant influence of the principles, but still they are subject to that influence, in a real manner, by the impulse which they have received from their predecessors, and by the habits which their mind has contracted. Thus it is, for instance, that all our natural philosophers admit the constancy of classes and laws, and consider generalisation as a progress, without going back to the thought of that Supreme wisdom which, for Descartes

[1] "Faraday, Inventeur," page 63.

and Leibnitz, was the warrant of these ideas. The savants of the third class deny the principles which have founded science; and it is their work which will supply the subject-matter for my demonstration.

Some, making profession of atheism, deny the existence of the unique Creator, mighty and wise. Others, who may have, as I have said, a religious belief in their capacity as men, think that the idea of God must be eliminated from science. The application of this false rule of method, if it were sincere and complete, would degrade us to a lower level than that of the thinkers of ancient Greece, who were enlightened, if not by the full light of truth, at least by the presentiment of it. This capital error presents itself under two forms: that of idealism, which regards the universe as the development of necessary laws, the manifestation of a principle without consciousness and without liberty; and that of empiricism, which will have nothing to do with direction in scientific researches, denies the value of principles, and ends almost always in materialism.

Idealism admits the order of the universe; but it denies the free power of its Author, and it leads to the supposition that reason is the universal principle, a principle without consciousness in nature, and which becomes conscious in humanity. It results from this way of thinking that man is able to find in himself the necessary laws of the universe. Hence the employment of the method of construction, or the *à priori* method, one which is found in Descartes in direct contradiction to the philosophical teaching of that author, but which proceeds, as a matter of course, and as a necessary

consequence, from the idealistic theory. That such a method naturally tends to put scientific research upon a wrong track, is a fact established most positively by the history of modern Germany. Idealism, which reached its apogee in the constructions of Hegel, was the occasion of a great loss of time to naturalists brought under its influence. Its influence has been still more pernicious, in that it has driven savants, by a violent reaction, into an excessive empiricism, which is a more pressing danger than the former, and which is likely to demand attention for a longer time.

The pretension to derive all human knowledge from experience alone, and the rejection of all principles, has been the occasion of the retrogression in the general theory of nature which characterises the end of the eighteenth century and the beginning of the nineteenth. The proofs of this affirmation are contained in our preceding study. Leibnitz pointed out the false direction which thought was taking, but he was not understood. While the materials of science were being collected; while chemistry was forming, and the application of mathematical calculation was developing the discoveries of Newton, the grand doctrines of the seventeenth century, which in our days have reappeared under the title of modern physics, underwent an obscuration. This obscuration was the result of the prevalence of empiricism, and of the error which placed under the patronage of Newton the philosophical tendencies of Bacon and Locke. During this period, a small number of savants maintained, contrary to the general opinion, the bases of the system of physics

which we hold for true. To mention but one of these, Euler continued to maintain not only the theory of luminous undulations, but almost all the grand principles of the Cartesian physics. Euler makes an exception in this respect: he makes an exception also by his profession of the great religious beliefs, at a period when they were violently attacked. Let us pass to a more modern epoch.

Atheism is reappearing, now for thirty years past, and is showing itself in philosophy, in the study of social questions, in natural history. It is its action upon the science of matter that we have to ascertain. The result of the inquiry is simple. The focus of the light being destroyed, the rays are extinguished. The negation of principles declares itself in men who necessarily apply them, but who would cease to produce veritable science if they followed in their consequences the theories which they profess. Here follow the proofs of this assertion.

Negation of the Principle of Simplicity.

They deny the principle of simplicity. This negation had, some years ago, for its secondary and accidental cause, the following circumstance:—Boyle in England, and, more recently, Mariotte in France, had established a law relative to the relations of volumes of gas to the pressures which they support. For a certain time it was believed that the law was absolute. M. Regnault ascertained that it has not this character, and that if it suffices for practical use, so that it may

be employed in mechanics without injurious error, it has not a complete exactness. The only consequence to be drawn from this and analogous facts is, that we often arrive at laws which are not universal, because they are the manifestation of the combined, and consequently variable, action of laws really primitive. This incident, however, disturbed a certain number of savants, who, upon occasion of it, were led to doubt whether nature is so simple in its processes as it is commonly supposed to be. This is a passing perturbation, the cause of which will disappear by the mere fact of the further progress of science. What follows is more serious. Savants placed under a philosophical influence opposed to the conception of universal order deny in an absolute manner the principle of simplicity. They do not say, "Beware of narrow systems which do not embrace the whole number of facts;" but, "Beware of making research for simplicity and order in nature." Bacon fell into this error, which flatly contradicts his beautiful theory of the scale of laws more and more general. "The human understanding," he writes, "by virtue of its natural constitution, is but too much disposed to imagine in things more uniformity, order, and regularity, than as a matter of fact is found in them; and although there is in nature an infinity of things extremely different from all the rest, and unique in their kind, it is always supposing a parallelism, analogies, correspondences, and relations, which have no real existence."[1] This, in Bacon, is the result of a blind reaction against the abuse of the systematic spirit, and

[1] "Novum Organum," livre i. § 45.

is, I repeat, the direct contradiction of the best part of his doctrine. But what is accidental in this case will become the rule in science, if we are to eliminate all guiding principle, to remain face to face with facts. Let us listen to M. Moleschott: "It has been said that nature always likes to take the shortest way; and they are forever repeating Boerhaave's favourite saying: *Simplicity is the sign of truth.* This view of things was closely connected with the hypothesis that nature was wisely governed; they did like the peasants of whom Riehl speaks, who, seeing nothing more costly in the way of holiday clothes than their *blouses*, clad with them the images of their saints on certain fête-days."[1] Boerhaave's favourite principle (Is M. Moleschott unaware of the fact?) is also that of Copernicus, Fresnel, Galileo, and Newton; Laplace gives it at full length in his works: it is the guiding principle of all the researches of modern physics. We should ponder M. Moleschott's words. He designates as an error "the hypothesis that nature is wisely regulated." But what then is all science, but the search for traces of this wisdom? The order of nature bears witness to a Supreme Ordainer; and we understand therefore that, in order to deny God, it is convenient to deny the principle of science. We have to do here with a beseiged garrison, which blows up the place rather than surrender.

[1] "La Circulation de la Vie," lettre 17.

Negation of the Principle of Harmony.

The negation of the harmony of the universe is closely connected with that of the simplicity of its arrangement. Experience reveals to us everywhere the multiplicity of beings and the diversity of phenomena; the study of the relations which make the harmony of things is the result of the rational instinct which leads us to the search for unity, for harmony is simply unity maintained in diversity. It is, therefore, not surprising that the value of the search for harmony should be disputed in the proportion in which empiricism prevails. This negation retards the march of science, and dissipates a part of the forces which should be employed in its service. M. Sainte-Claire Deville, for instance, desires to study the relations which exist between chemical affinity and the general laws of physics; that is to say, he seeks for the harmony of two orders of phenomena. M. Naquet, one of the editors of the *Philosophie Positive*, administers to him for this a sufficiently sharp censure. He protests in the name of immediate experiment, against inquiry after the supposed relations, and would have investigation stop at the special properties which tend to make bodies unite, without pretending to go farther.[1] Newton sought to connect the phenomenon of gravitation with the movements of the ethereal fluid, and we have seen Faraday point out an analogous research when speaking of the relations of magnetism and gravity. Auguste Comte sets himself strongly

[1] *La Philosophie Positive,* revue dirigée par MM. Littré et Wyrouhoff, voir le No. de Septembre-Octobre, 1867, page 319.

against these researches directed towards the discovery of universal harmony. "We evidently cannot know," says he, "what are *au fond* that mutual union of the stars, and that weight of terrestrial bodies; any attempt whatever in that direction would be, of absolute necessity, profoundly illusory, as well as perfectly idle; only minds entirely foreign to scientific studies would be so occupied at this day. . . . For the geometrician, whom long and habitual meditation has profoundly familiarised with the true mechanism of the celestial motions, terrestrial weight is accounted for when he conceives of it as a particular case of general gravitation. On the contrary, it is weight which explains the celestial gravitation to the physicist properly so-called, as well as to the vulgar, the notion of it being to him sufficiently familiar. We never can really go beyond such comparisons."[1] The school of Comte has followed the master, and translated the fact that all bodies known to us are heavy by the idea that weight is inherent in matter. It is possible, no doubt, that gravitation may always remain for us a phenomenon without known antecedent—a starting point; but to proscribe *à priori* the research for possible relations between weight and the motions of ether, is to bar a road in which science will perhaps be making great discoveries.

Negation of the Principle of Constancy.

The principle of the constancy of laws and classes is

[1] *Cours de Philosophie Positive*, Leçon 24e, tome ii. pages 246 et 247, de la première édition.

denied by the empiricism of the day, as are the principles of simplicity and harmony. M. Littré says that experimental laws are not *necessary* laws, which assuredly is true, and implies the ligitimate negation of idealistic theories; but he goes farther, and denies that the idea of the fixity of laws is one of the bases of science. "Since the time of Newton and his successors, a very recent date, we are unable to conceive of matter without gravitation. Modern astronomers have undertaken observations of long continuance upon double stars which revolve one about the other. If in this motion they obey the laws of gravitaton, it will be established that in our nebulous space,[1] and amongst our millions of stars weight exerts its sway; but it would be rashness and presumption to affirm that, away from our *nébuleuse,* other conditions do not govern another form of matter."[2] Granted that the author may be right when he says that there may be worlds the laws of which are not those of that which we are able to observe; yet each one of our discoveries warrants the affirmation that there exists a harmony between our thought and the reality, because God has been pleased to render intelligible to us the world in which we are placed. M. Littré would make of the fixity of the laws in our nebulous space an affirmation purely experimental in its origin; but it is easy to understand that that cannot be. The observations upon double stars, of which that savant speaks, are made by means of light, but those observations are of

[1] *Dans notre nébuleuse.*

[2] *Journal des Débats,* du 6 Février, 1866.

value only because we admit that the laws of the propagation of light are the same in the region of the fixed stars as in our system. If it were admitted that light was propagated otherwise in one part of space than it is near to us, astronomy would be impossible. Astronomy cannot, therefore, establish experimentally the fixity of the laws except by supposing that they are fixed.

Negation of the Principle of Causality.

We have now encountered the negation of the principle of simplicity, the principle of harmony, and the principle of constancy; we have still to find the negation of the principle of causality. Here it follows in formal terms: "I am convinced that if a man accustomed to abstract reasoning and analysis were honestly to employ his faculties to that effect, he would find no difficulty, when his imagination should have taken that direction, in conceiving that in certain places,—for example, in one of the firmaments of which sidereal astronomy at present makes the universe to consist,—events may succeed one another by chance, without any fixed law; and nothing, either in our experience, or in our mental constitution, gives us sufficient reason, or indeed any reason whatever, for thinking that that nowhere takes place."[1] Such is the opinion of Stuart Mill. So, following up this thought, M. Taine remarks: "We should come to look upon the universe as a simple heap of facts. No inner necessity would produce their connection or their existence. They would be mere

[1] Stuart Mill. See "Le Positivisme Anglais," by H. Taine, pages 102, 103.

data,—that is to say, accidents. Sometimes, as in our system, they would be found collected in a way to bring about regular returns, sometimes they would be so assembled as not to bring about any at all. Chance, as in Democritus, would be at the core of things. Laws would be derived from them, and would be derived from them only here and there."[1] M. Littré expresses, on his own account, opinions of the same order: "We cannot conceive that nothing comes from nothing, and that nothing returns to nothing; but, in fact, what do we know about it? Is not all that we are permitted to say confined to the affirmation that, within the limits of our experience, nothing comes from nothing, and returns to nothing, and to giving to this notion all the induction which is allowed by the vast extents of duration and of space open behind and before us?"[2] Here we have the death-warrant of science. The principle of causality is the essential basis of the reason. Suppose the possibility that nothing comes from nothing, and all research is ended. We see here, with the clearest evidence, how the absence of faith in God, the universal Cause, ruins thought in its foundations.

The negation of the principle of causality has besides a special source in a false interpretation of the idea of progress. Progress is a law; it is the expression of an order in the succession of facts. The idea of progress, when the word is employed in a favourable sense (there is a progress in evil), supposes the conception of good as the end towards which things are tending, and the

[1] Stuart Mill. See "Le Positivisme Anglais," by H. Taine, page 105.
[2] *Journal des Débats*, du 6 Février, 1866.

conception of a cause which is directing things towards that end, and of which the progress manifests the mode of action. But it comes to pass that progress is taken for a cause,—that is to say, that the cause is suppressed: this is the consequence of empiricism, of neglect of the laws of reason. We see, for instance, a plant issue from the ground, and the unfolding in succession of its stalk, branches, flowers, and fruits, presents to us a development, a growth of being, a progress. The laws of reason demand that we assign to this development an efficient cause in the germ from which the plant has proceeded. If this is forgotten, the idea is encouraged that things produce themselves, and that, by virtue of what is called progress, the more may proceed from the less. This *more* which proceeded from the less would in reality proceed from nothing; and so we have here the direct negation of the principle of causality. This is, moreover, the overthrow of the foundations of science; for the man who has learnt to do without causes in the explanation of phenomena, if he remains faithful to his opinions, will certainly not make any discovery.

Negation of the Inertia of Matter.

After the negation of the guiding principles of science, we shall meet with the negation of the inertia of matter. A curious spectacle it is which those writers present who, at an epoch when the mechanical character of physical phenomena is the fundamental thesis of science, deny the law of inertia, which is one of the

essential bases of mechanics. As M. Renouvier has remarked,[1] the science of modern physics, sprung from the movement of which Descartes is the principal author, offers two principal characters: the fixing of the object of science in mechanics, and the clear and definite separation of the domain of physics from that of psychology. The second of these affirmations was the condition of the first: in order to reduce material phenomena to the mechanism of inert matter, it was necessary to take from them all idea of active properties, and of psychical attributes of any kind whatever. The principle of the inertia of matter did not want opponents; but, as Euler remarks, it has been proved by its results, since it is found at the base of all modern discoveries. There is going on, however, in our own day, a marked reaction against this doctrine.

This reaction has secondary sources, and in particular two which I will mention. The progress of physiology has been one of the occasions of error. The recourse to vital force, employed in a vague and indefinite way for the explanation of phenomena, has long injured the progress of the study of organised bodies. Science, as it advanced, has shown that it is possible to produce artificially in a laboratory material substances which had been thought to be the exclusive product of living beings: it has, moreover, demonstrated the analogy, and often the identity, of organism with physical phenomena. In connection with these real discoveries have been produced two confusions of ideas: the first is that of organic products, some of which can be com-

[1] *La Critique Philosophique*, du 5 Mars, 1874.

posed artificially with organised matter, no element of which has ever proceeded from a laboratory. M. Naquet in his "Traité de Chimie," has pointed out this error with great distinctness. The second confusion has been that of the explanation of physiological phenomena, the organism once given, with the origin of the organism itself, a confusion which did not exist in the minds of Descartes. Descartes, in fact, in his doctrine of the automatism of the beasts, always admitted that the animals were machines constructed by the infinite wisdom of the Creator. The theory of transformism badly interpreted came to mingle as an affluent with the current of error. From the certain fact that living beings are modified by physical causes, inattentive minds have passed to the absolutely different idea that living beings might be nothing but a mere modification of inorganic matter. So, reviving the Greek materialism, the idea has been conceived of a matter which should be the unique origin of all things, and so, theoretically, physics and physiology are made to be one and the same. Still it is very difficult not to recognise in living beings a spontaneous principle of motion, so that in order to reduce physics and physiology to unity, a strong temptation is felt to deny the inertia of matter; that is, in fact, to say, that under the appearance of reducing physiology to physics, one rather reduces physics to physiology.

The same result, the negation, namely, of inertia, has been reached by another road. In a lecture delivered to the Academy of Sciences at Vienna, on the 30th of May, 1870, M. Ewald Hering distinguishes, with perfect

precision, the point of view of the physiologist, for whom man and the animals are only aggregates of matter to which physical laws apply, and the point of view of the psychologist who takes into consideration the phenomena of sensation, intelligence, and will, phenomena which are known to us only by consciousness, or the inner sense. He points out that the union of these two points of view is indispensable for the complete study of man, and that the physiologist, shut up in the sole study of objective and material facts, has no means of understanding human existence. After these prolegomena, which remind us of those of Descartes, the author expounds the close correlation of physical and psychical phenomena, and directs his attention particularly to the study of the memory. The memory, a fact of the inner sense, has for organic condition a certain arrangement of the cerebral molecules. Having so explained himself, the author describes the memory as "a faculty of the cerebral substance." He says that "the nervous substance faithfully keeps the *souvenir* of the functions which it has often exercised;" and his work is entitled "Sur la Mémoire comme Fonction Générale de la Matière Organisée." The author has taken his precautions that his words may be understood in their real and true meaning, as expressing the intimate relation which unites dissimilar phenomena; but the expressions which he employs are full of peril, and big with confusions of ideas. Readers placed under certain philosophical influences are in danger of forgetting M. Hering's prolegomena, and understanding him to mean that memory is a function of

matter. Then the inertia of matter would be denied by the attributing to the body, not only a spontaneous principle of motion, but phenomena properly spiritual. I have insisted upon this example, because the mischievous passage from the certain truth of the organic conditions of thought to the error of the identification of spiritual with material phenomena seems to find a place, in this day, in the minds of not a few naturalists. Biology is a more complex science than physics: it is not surprising that it is comparatively behind-hand, just as the science of physics was for a long time behind-hand as compared with the simpler science of mathematics. It is, at the present time, the occasion of many confusions of ideas, which cast their shadow upon physics, and which will not cease until biological conceptions shall have attained to a degree of clearness, in which they are still wanting.

Such are the accidental sources which furnish nutriment to the negation of the inertia of matter. This negation, when it is affirmed seriously, and in a deliberate manner, has for essential cause the doctrine which excludes from science the idea of the Supreme will, the cause of universal motion, and so compels the placing in matter itself the principle of its motion. We will give a few examples of this negation.

Mr. Tyndall puts the question of the origin of life, and he says, going back to the idea of primitive nebulous matter: "Two hypotheses present themselves; either life was virtually in matter in the nebulous condition, from which it has proceeded by a natural development; or life is a property which has been conferred upon

matter at a subsequent period."[1] These two hypotheses are contrary, both one and the other, to the idea of matter which has founded modern physics. A natural development of matter can only produce mechanical phenomena. If life is a pure mechanism, it did not exist virtually in the elements of the *nébuleuse,* it existed there actually, if not in its diverse and successive manifestations, at least in its principle. Life would not exist virtually in matter, in the way of distinct reality of motion, except matter had the power to produce something else than itself, which is the negation of its inertia. As for the second hypothesis, life cannot be considered as a property conferred upon matter. If there is not a defect here in the thought, there is at least in the expression. Matter subjected to the action of life is the sole idea compatible with the notions of modern physics; *living matter* is an improper expression, which, taken literally, becomes an error. What follows is more serious.

In a speech delivered, in 1874, to the British Association for the Advancement of Science, Mr. Tyndall suggested to his hearers the idea of renouncing "the definitions of matter given in our classical books, which had as their object to cover its purely physical and mechanical properties."[2] He reckons therefore that we must acknowledge that matter has other properties beside physical and mechanical properties, and he gives this definition of it, into which anything

[1] "Sur l'Usage Scientifique de l'Imagination" (en anglais), Brochure in-8. Londres, 1870.

[2] *Revue Scientifique* du 19th Septembre, 1874.

in the world can enter: "The dawn and the power of all the forms and all the qualities of life." Such an affirmation made, in 1874, in a scientific congress is a fact well calculated to secure our fixed attention. Our science was founded by taking away from the conception of matter all *power* other than that of resistance in the parts of space which it occupies, of communicating motion, and of modifying it as the effect of that resistance. Hence that reduction of corporeal phenomena to mechanics, affirmed by Descartes and reasserted by Newton. To introduce into the definition of matter "the power of the qualities of life" is the direct negation of inertia; it is a positive reaction against the bases of physics; it is, in short, the revival of the theory of substantial forms and occult causes. Mr. Tyndall adopts a history of philosophy which reproduces views put forth by Bacon. He lowers the part taken by Socrates, Plato, and Aristotle in the development of human thought to glorify Democritus, Epicurus, and Lucretius. This way of understanding the history of science does not agree with the views of the author. Matter, "the dawn and power of the qualities of life," resembles much more the water-principle of Thales, and the intelligent air of Anaximenes, than the atomism of Democritus. The speech of Mr. Tyndall turns upon the *historical evolution of scientific ideas.* It is surprising that, at an epoch when the science of mathematical physics is developed with so much *éclat,* the author does not seem to perceive the importance of the school of Pythagoras, and that, while pointing out the doctrine of the conservation of energy as an important

characteristic of contemporary science, he passes over in complete silence the origin of that theory in the mind of Descartes, and its development in the labours of Leibnitz.

In the quotation borrowed from Mr. Tyndall, the only question has been that of life, into which, however, the author seems to introduce psychical phenomena.[1] M. Du Bois-Reymond is more explicit in this respect. In a discourse, addressed to the Association of German Naturalists and Physicians assembled at Leipzig, he begins by showing, with a clearness which it would be difficult to surpass, how impassable for our minds is the abyss which separates material facts from spiritual phenomena of the soul.[2] He goes on to observe that it does not thence follow that spiritual phenomena are not the result of their material conditions, and he illustrates his thought by the following example: "Let it be imagined that all the atoms which constituted Cæsar at a given moment—at the Rubicon, for instance—were put each in its place by the help of a mechanical artifice, and that the requisite velocity were communicated to them in the proper direction; then, according to us, Cæsar would be reconstituted, body and soul."[3] The author therefore, without professing to know *how* the atoms produce thought, still does know, and asserts, that they have the power to produce it. The following is a thesis analogous to that of the Berlin professor, stated by a French writer:

[1] See the Fifth Study.
[2] See the text of M. Du Bois-Reymond, quoted in the Fifth Study.
[3] *Revue Scientifique* du 10 Octobre, 1874.

"In certain conditions, matter produces light, heat; in other conditions, it feels, wills, and acts; in other conditions again, on a higher scale, it manifests itself as thought, it acquires consciousness, it arrives at spiritual life."[1] It is almost superfluous to remark that the matter which wills and acts is a conception carefully eliminated in the prolegomena of all our treatises on mechanics.

It only remains, in order to complete my proof, to find the negation of the law of inertia expressed in the very terms in which it is customary to state the law; and this negation we have as follows from the pen of M. Moleschott: "One of the most general characteristics of matter is to be able, under propitious circumstances, to put itself in motion."[2] What are the *propitious circumstances* which allow of matter putting itself in motion? I do not know what, on this subject is the doctrine of the author.

The promised demonstration is now complete. The negation of the fundamental idea of bodies; the negation of the guiding principles of researches; the negation of all the bases of modern physics: we have found what we were looking for. This insurrection against the foundations of science may have accidental and secondary causes; but its principal cause is that the radiating centre of principles is extinguished, by the fact that the idea of God is either denied or eliminated from the domain of science. There is then produced a

[1] Edmond Scherer, "Mélanges d'Histoire Religieuse," Paris, Michel Lévy, 1865, page 184.

[2] "La Circulation de la Vie," lettre 17.

sort of intellectual blindness: the sense of the need of unity, which is the foundation of the reason, not finding its legitimate satisfaction in the thought of the Supreme Cause which establishes the relation of bodies and spirits, throws itself upon a single one of the elements of this relation, and seeks to make everything proceed from matter. M. Dumas tells us: "To doubt of divine verities, is to give over one's life to chance; to believe in them, is to give it its ballast: such were the conviction and the rule of Faraday."[1] The foregoing considerations allow us to translate this affirmation in this way: "To doubt of divine verities, is to give over science to chance: to believe in them is to give it its ballast: such is the lesson of history."

We must not, to be sure, be entertaining too much anxiety about the future of science. Settled upon the grand bases of the human reason, and confirmed by three centuries of discovery, it has acquired a temperament robust enough to reject the morbid principles which a bad philosophy tends to introduce into its bosom. And besides, the writers who deny its essential bases cannot accomplish any scientific labour without justifying, by employing them, the principles which they reject in theory. M. Littré, if he had practised chemistry, would never have accounted for the results of an analysis by the supposition that something had proceeded from nothing. Mr. Tyndall will never deduce the explanation of a biological fact from the formula that matter is the dawn and power of the qualities of life. It is the lofty prerogative of truth (and this is true in all its provinces) to impose itself upon those

[1] "Éloge Historique de Michel Faraday."

who deny it, and who cannot deny it except by placing themselves in contradiction with themselves.

It remains established, therefore, that the two ideas of the immateriality of the soul and the existence of God lie at the foundation of modern physics, and that the negation of these verities would dry up the sources of science. The brilliant success of physical science, as it was conceived by its founders, in the seventeenth century, confirms the principles which directed their researches, and the belief which is the centre and the point of support of those principles. The idea of the absolute separation of the religious idea, in its philosophical generality, from experimental science, or of its opposition to it, is doubly false: It is false in principle, reason demonstrates it: it is false in fact, history proves it.

Protestations of some Contemporary Savants.

It has been said, again and again, and in so noisy a way, that science leads to the negation of religion, that men who have a right to speak have felt constrained to reply to these assertions, and such men in our days are growing more numerous. I shall content myself with adding a few instances of this to words which I have already quoted from Robert Mayer.[1]

The following is the conclusion of the work of Dr. Oswald Heer upon the "Monde Primitif de la Suisse:—"However grand be the edifice of the Creation, it cannot be appreciated in its magnificence except by intelligences qualified to judge of it. An example will make this clearer. Take a symphony of Beethoven;

[1] See the First Study.

the musical artist alone will understand its meaning: for him every note will have its signification, and from those various notes bound together will proceed a matchless harmony. The like is the case with nature. Phenomena taken separately, like detached notes, do not appear in their true meaning, which only comes out when we know how to unite them, and appreciate them as a whole. It is only by the bringing together of isolated facts that we form to ourselves an idea of the grandeur of the creation. It is only by this comparison that our minds obtain a glimpse of the harmony of nature, a harmony which, in the same way as its sister in the domain of sounds, lifts us above the physical world, and produces in our souls the presentiment of a Divine intelligence which is directing all that is, even as it has directed all that has been. Every one, no doubt, would take the man for an idiot who should pretend to say that the notes of a symphony are nothing but points thrown hap-hazard upon paper. But it seems to me that those are not less insane who see only a game of chance in the far more marvellous harmony of the creation. The more we advance in the knowledge of nature, the more profound also is our conviction that belief in an Almighty Creator and in a Divine wisdom which has created the heavens and the earth according to an eternal and preconceived plan, can alone solve the enigmas of nature, as those of human life. It is not the human heart alone which attests the existence of God, it is also nature."[1]

In 1860, M. Auguste De la Rive concluded a course

[1] "Le Monde Primitif de la Suisse," traduction Isaac Demole, 1872.

of physics, as follows :—"If I have learned anything in the long years of a study which has made one of the delights of my life, it is that God is continually acting; it is that His hand which created all, is watching over all in the universe. And this same Providence, which holds in equilibrium the forces of nature, which guides the stars in their courses, has an eye also upon each one of us. Nothing happens to us without the special will of Him who keeps us. In this profound conviction the Christian soul reposes in peace."[1]

I add now the declarations of two of the first chemists of our time. In the autumn of 1874, M. Chevreul said to the Academy of Sciences of Paris :—"I have asked myself whether, at an epoch when more than once it has been said that modern science leads to *materialism*, it was not a duty for a man who has passed his life in the midst of his books and in a laboratory of chemistry, in the search after truth, to protest against an opinion diametrically opposed to his own. . . . I have the conviction of the existence of a Divine Being, the Creator of a twofold harmony; the harmony which governs the inanimate world, and which, first of all, the science of the celestial mechanism reveals and the science of molecular phenomena; and then the harmony which governs the living organised world. Never, therefore, at any period of my life, have I been a materialist, my mind not having been able to conceive that that double harmony, or, again, that the human mind has been the product of chance."

[1] M. De la Rive's course was given at Geneva, and the conclusion was published in a journal of that city.

M. Wurtz, Dean of the Faculty of Medicine of Paris, expounded the theory of atoms to the French Association for the Advancement of Science, met at Lille, in August, 1874. He concluded his discourse as follows:—"Such is the order of nature; and in proportion as science has deeper insight, it brings to light at once the simplicity of the means set in operation and the infinite diversity of the results. So, across that corner of the veil which it allows us to lift, it lets us obtain a glimpse at the same time of the harmony and depth of the plan of the universe. As for first causes, they remain inaccessible. There begins another domain which the human mind will always be eager to approach and to survey. It is so made, and you will not change it. In vain science shall have revealed to it the structure of the universe and the order of all the phenomena; it desires to mount higher, and in the instinctive conviction that things have not in themselves their *raison d'être*, their support, and their origin, it is led to subordinate them to a first, unique, universal cause—God."[1]

Messieurs De la Rive, Heer, Chevreul, and Wurtz are men whose scientific eminence no one would venture to question. I conclude by oberving that when science recognises and proclaims "the harmony and depth of the plan of the universe," it does but confirm the principles which we find at its starting-point. Reason, rendered fruitful by experience, justifies the presentiments which directed the mind in its attempts to explain the phenomena.

[1] *Revue Scientifique*, du 22 Août, 1874.

FOURTH ESSAY.

Physics and Morals.

THE progress of science in the present day has established closer and closer relations, on the one hand, between physics and physiology, and on the other, between physiology and psychology. As we follow out this direction of thought to its consequences, we easily come to believe that the spiritual order is threatened in its bases by the study of the phenomena of matter, and that, in particular, a dangerous conflict is threatened between physics and morals. The object of this fourth study is to show that thoughts of this kind involve a great error.

DISTINCTION BETWEEN PHYSICAL AND PSYCHICAL PHENOMENA.

The phenomena of sound, heat, and light, when we regard them at once in their proper nature and in the knowledge which man acquires of them, suppose:— (1) matter in motion; (2) the presence of beings capable of sensation and perception; (3) harmony according to fixed laws between material and spiritual

facts. Motion being once disengaged from the impressions which correspond to it, there comes at once into clear view the absolute difference between material facts perceived by the senses and psychical facts perceived by the consciousness. It is no longer in men's power, as it once was, to conceive of the physical properties of bodies as a transition between pure mechanism and spiritual phenomena. Take away beings capable of sensation, and the mechanical condition alone remains and in perpetuity.

To say that "thought is a movement of matter"[1] is to maintain an absolutely desperate thesis. In fact, the question is to include thought as a species, in motion considered as a genus. Now, motion is specified only by its velocity and its direction. Vainly should we turn these two ideas over in all directions, we should never get anything out of them, I do not say identical with, but in the most distant degree analogous to thought, or to any fact of consciousness whatever. Recent labours are in danger of creating in this respect an illusion easy to prevent. Contemporary savants calculate the velocity and direction of corporeal motions which answer to psychical phenomena. It will be possible perhaps to determine with accuracy the time necessary for an external impression to be perceived by means of the centripetal action of the nervous system, and for a feeling or wish to be carried outwards by means of the centrifugal action of the same system. These researches are interesting; but we must well estimate their possible result. They will give greater

[1] Moleschott, "La Circulation de la Vie," tome ii. pages 178 et 179.

precision to the theory of the relations between physics and morals, but without at all diminishing the distinction between those two elements. After all observations and all calculations, it will be always inconceivable that a displacement of molecules, or an undulation, or a vibration, or any mechanical phenomenon whatever, should be, not the condition of thought, but thought itself. The identity of corporeal and spiritual phenomena is an affirmation which must be consigned to the class of impossible hypotheses.[1]

The doctrine of transformism throws a veil over the clear certainty of this truth. "Motion is transformed into thought" is a formula which less directly shocks the reason than that other formula: "Thought is a motion;" and yet substantially the two affirmations are the same. The thesis of the transformation of motion into thought claims our fixed attention, because it has been maintained of late by Mr. Herbert Spencer. This author accumulates proofs, as it is easy to do, of the close relations which exist between psychical phenomena and the condition of the organs; and then, instead of inferring the harmony of two orders of distinct facts, he infers the transformation of the one into the other. He writes: "The law of metamorphosis which prevails among physical forces, prevails equally between them and mental forces. The modes of the Unknowable which we call motion, heat, light, chemical affinity, &c., are transformable one into the other, and into those modes of the Unknowable which we distinguish by the names of emotion, sensation, thought;

[1] See the "Logique de l'Hypothèse," pages 73 à 76.

these in their turn may, by an inverse transformation, resume their previous forms."[1] And what is this to say? "The motion of bodies is modified according to the resistances encountered, and the meeting of the different forces in operation; but it is modified without ceasing to be purely and simply motion. When we speak of transformation, the sense of the word, if we only took heed to it, would prevent many errors. A change of form is not a change of nature. To say that motion is transformed into sensation and thought, is to say that thought is a form of motion, and consequently that it is a motion. The formula of transformation is, therefore, substantially the same in meaning with that of identity.

Mr. Spencer is the victim of an illusion, the origin of which it is not difficult to discover. He knows, as we all know, that heat considered in an objective manner, —that is to say, isolated from the psychical phenomenon of sensation, is only a motion. He sets forth this doctrine, which applies to phenomena of light as also to those of heat, in the following terms:—

"The mode of force, which we call heat, is now regarded by physicists as a molecular motion, not as a motion such as that which is manifested by the change of the relations which masses appreciable to the senses undergo between themselves, but which is produced among the units of which those sensible masses are composed. If we cease to conceive of heat as the particular sensation occasioned to us by bodies under certain conditions, and if we consider the other phenomena

[1] "Les Premiers Principes," page 232.

which those bodies present, we do not find in them, or in surrounding bodies, or at once in them and those bodies, anything but motion."[1] The author who traced these lines loses sight of the consequences of the truth which he has himself enunciated. If he said mechanical motion, or that of the transport of masses, is transformed into a molecular motion which is transformed into an etheric motion, to which answers the sensation of heat, he would indicate the changes of form presented, according to the diversity of the aggregates, by the single phenomenon of motion; but he says that motion *becomes* heat or light, as if the question were, not of another form, but of another nature. This is not a transformation, in the primitive and perfectly intelligible sense of that term, but a veritable *transmutation,* in the sense of the alchemists of the Middle Ages. The vague and false idea that motion by becoming heat and light becomes something else than itself, and that in an incomprehensible way, leads Mr. Spencer to think that in a way also incomprehensible, motion becomes sensation and thought. I read his words again: "The law of metamorphosis which prevails among physical forces, prevails equally between them and mental forces. The modes of the Unknowable which we call motion, heat, light, chemical affinity, &c., are transformable one into the other, and into those modes of the Unknowable which we distinguish by the names of emotion, sensation, thought; these in their turn may, by an inverse transformation, resume their first form. . . . How does this metamorphosis take

[1] "Les Premiers Principes."

place? How can aerial vibrations engender the sensation called sound? How can forces set at liberty by chemical changes wrought in the brain produce an emotion? These are mysteries which it is not possible to fathom; they are not more profound than the transformation of physical forces one into another. They do not farther exceed the reach of our understanding than does the nature of Spirit and of Matter. They are simply, like other final questions, questions which cannot be solved."[1]

The relations of the various motions of matter with the sensations which correspond to them constitute certainly a question which cannot be solved, as do all final questions; these relations are a primitive element of the constitution of things, the explanation of which cannot even be sought for, because it is impossible to imagine in what direction one should look for it. But to identify, as regards intelligibleness, or rather the absence of intelligibleness, the changes of form of motions,—that is to say, of the direction and velocity which depend upon the nature of aggregates,—with the transformation of motions into psychical phenomena, is a manifest error. The mind has no trouble in understanding that a motion of translation arrested becomes a molecular motion, and that a molecular motion produces undulations in the ether. All this belongs to the same order of objective appearances, and it is easy to conceive that if we were provided with organs

[1] "Les Premiers Principes," pages 232, 233. M. Renouvier has given an excellent critique of this passage in the *Critique Philosophique* of the 10th October, 1878.

capable of perceiving the molecules of bodies and of the ethereal fluid, we should be able to follow these transformations of motions as we follow, in the working of a piece of mechanism, the motion of a wheel producing the motion of another wheel. But the transformation of motions perceived into perception, and of motions felt into sensation, causes the mind to pass from one world to another. We have no longer to do with one and the same order of objective appearance where all hangs together without difficulty for the thought; we have to pass from sensible observation to psychical observation, which is of another order. To identify the two orders is, as Charles Secrétan has said, "to pronounce words, the sense of which it is impossible to realise."[1]

We have here an example of a phenomenon acquaintance with which is indispensable for the understanding of the history of philosophy. I am speaking of the bewilderment which a new idea produces, by the dazzling effect of which the new idea assumes extravagant importance, so that the subject of it exclaims: All is there! Pythagoras having, by an intuition of genius realised how great a part mathematics were to play in the science of nature, comes to think, and say: "Number is everything." Condillac, under the impression of the discoveries made in his time on the subject of the influence of signs upon thought, declares that "science is only a well-constructed language." Hégel, seeing that the laws of logic are met with everywhere, in the order of nature as well as in our conceptions,

[1] "Discours Laiques," page 156.

proclaims that "Logic is everything." A fact of the same order is produced in Herbert Spencer. Dazzled by the theory of the transformation of motions, he exclaims: "All is there!—and human thought is only a motion transformed."

The progress of physics soundly interpreted is far from leading to such results as these; on the contrary, in proportion as it reduces all the objective part of phenomena to motion alone, it is making wider the separation between material elements and psychical elements, between body and spirit. This is unquestionable; but, at the same time, the progress of physiology is establishing still more intimate relations between two classes of facts which the progress of physics is distinguishing without separating them. The idea was long entertained, independently of materialistic schools, that the vital phenomena were almost without relations with physico-chemical phenomena, and had their explanation in the proper action of the vital force. Contemporary science is advancing resolutely in a contrary direction. The complete identity, to be sure, has not been established between the phenomena of living beings and those of inorganic matter. But very lately Claude Bernard was still insisting that "the chemical phenomena of the living being, although they take place according to the general laws of chemistry, have still their special processes and modes of action," so that "the chemical phenomena of living organisms can never be completely assimilated to phenomena which have their origin independently of them."[1] But, an

[1] "Leçons sur les Phenomènes de la Vie Communs aux Animaux et

indispensable reserve being made for the presence of the living organism, always necessary for the explanation of the phenomena of life, modern science is tending more and more to bring under the laws of physics and of chemistry the functions of respiration, circulation, the secretions, and, by a natural induction, the functions of the cerebral system. If physical and chemical phenomena are only motions, it follows that, the organism being given, all manifestations of life are mechanical phenomena. This granted, and if we allow again that all feelings, all ideas, all impulses, all volitions have corresponding phenomena in the domain of matter, it follows that if we suppose a transparent cerebral organ, and an observer capable of perceiving all and knowing all the laws of physiology, such an observer would read in the cerebral organism all the psychical phenomena (feelings, ideas, wishes), just as we read all the thoughts of a writer in the different arrangements of the letters of the alphabet. This is an inductive hypothesis. I admit it, if not as absolutely demonstrated, at least as invested by contemporary science with a high probability. When the essential difference of corporeal and psychical phenomena shall be well understood, their identity will not be inferred from their relations; nor will the extravagant idea be entertained, which figures in some writings of the present day, that physiology will be able to replace psychology. Those who talk in this way forget that they would have no idea of the phenomena of conscious-

aux Végétaux, page 166. See also "Rapport sur les Progrès et la Marche de la Physiologie Générale."

ness if they had not the immediate inner knowledge of them, and if they were reduced to the mere observation of physiological facts, which are nothing but motions. They seek in physiology for the signs of psychical phenomena, the knowledge of which is manifestly the necessary and previous condition of the researches to which they devote themselves.

From the relations of physics and morals two consequences ensue. The first is the moral importance of hygiene. Our *penchants* are determined by the state of our organs. This is evident with regard to *penchants* properly speaking sensual; and if we reflect we see at once that all psychical phenomena are subject to the same law: the state of the understanding, the feelings, and the will has physiological conditions as well as our various appetites. To be assured of this it is only necessary to consider the effects of alcohol and of narcotics upon the spiritual functions. Hygiene, regimen, the discipline of the body understood in its widest sense, have therefore an evident influence upon morals; and this is a truth to which it is impossible to give too much attention in the education of the young and in self-government. Hence it follows that progress in the study of the relations between physics and morals has a very real importance for the spiritual good of humanity. Savants of the present day, who search into these curious questions, are often swayed by a spirit of materialism, but they are scattering seed the while which promises to moralists and those who are engaged in education an abundant harvest. The second con-

sequence which follows from the relations of physics and morals is the physiological importance of virtue. I take here the term *virtue* in its etymological and direct meaning, according to which it marks the effort the result of which, in what concerns the object of my study, is to maintain the functions of the senses within their just limits, and to prevent the excesses which pass the bounds of the requirements of the organism. That vice, moral cowardice, and the shrinking from effort have a large share in the production of maladies, and in the causes of death, is a fact not to be disputed.

The two consequences which have just been pointed out suppose in man a principle of liberty. In the case of the second this is evident, as there is supposed a direct appeal to the reasonable and free will, against the involuntary impulses of the senses. For the first, it is not less evident in reality, because the counsels of hygiene and regimen suppose, equally with the directions of the highest morals, the existence of a reasonable and free will to which reference is made. We repair machines when they are out of order, and do not give them advice.[1] Hygiene is a science, no doubt;

[1] M. Fouillée considers this argument as a paralogism (*Revue Philosophique* of December, 1882, page 588). He writes: "We do not give advice to a machine, because it has neither ears nor understanding; we give it to men about their health and regimen, because they are intelligent; but it is of no use to this end that they should be free." What would an intelligent being be without any element of liberty? A conscious mechanism; and the fact of his consciousness (supposing it possible) would not take away from him his specific character. Assuredly, as M. Fouillée remarks, in giving advice one wishes to exert an influence; but this is the question: Does the man who gives advice intend to act in a compulsory way upon a being subjected to the law of

but, as Jean-Jacques Rousseau said, it is a virtue still more than a science, because its most important prescriptions are very elementary, and are not, in the greater number of cases, unknown to those who violate them. But the question is this: Does the reduction of physiology to physics, and the establishing of the close relations of physiology with spiritual phenomena, allow of the admission of the existence of liberty? In following the course of thought to which this question leads us, we shall find ourselves in the midst of the conflict between physics and morals.

Apparent Conflict between Physics and Morals arising from the Principle of the Conservation of Energy.

All spiritual phenomena are manifested by motion. How do men communicate one to another their feelings, their thoughts, and their wishes? They have but three methods at their disposal—gesture, speech, and look. Gesture is a motion of the limbs; speech is a movement of the vocal organs transmitted to the surrounding air; and what is a look, the power of which is at times so great? What is there between the eye which looks and the other eye which, in a look, reads instinctively pity, anger, pride or humility, love or hatred? The undulations of ether—that is still a motion. There-

inertia, or to furnish motives for decision to a being capable of choice? It is for psychological observation to decide. M. Fouillée had seen my fourth essay in the *Revue Philosophique*, in which it was originally published.

fore, at least within the limits of our ordinary and scientifically ascertained experiences, minds communicate with one another only by means of matter. And this is not all. Thought, feeling, will, which are only communicable by an external motion, are not produced but in an indissoluble relation with cerebral phenomena, the theory of which is far from complete, but which science is resolutely seeking to determine as molecular motions. Of course, we have no right to affirm, in an absolute sense, that there cannot exist thoughts without a cerebral organism; this would be an absolutely unwarranted induction. The inhabitant of one of the isles of Oceania who should affirm that the fauna and flora of the entire globe are identical with those of his own island would make an assertion not more imprudent than would be that of a savant who should infer, from the conditions of the spiritual phenomena observed upon our globe, the conditions of those same phenomena in the entire universe. That there exist, under other conditions than those of humanity, spirits—that is to say, beings capable of thought and will—is what a serious and prudent experimental science cannot affirm, and has not the right to deny. But, *within the limits of our actual experience*. mind is not manifested to itself or to others except under the condition of cerebral functions. When Descartes affirms that he is conscious to himself as spirit, without knowing whether he has a body, this great man forgets that he has at times experienced, after a prolonged exercise of thought, a fatigue of the head, and that fatigue has revealed to him the intervention

of the organism in the intellectual functions. If he had studied this subject more attentively, he would have found that observation, pure and simple, without any notion of physiology, is sufficient to make it certain that the brain is the organ of thought.

The cerebral functions are the condition of thought. The cerebral functions are motions. Therefore, motion is the condition of all mental acts. Motion is subject to fixed laws, and, for the science of the present day, one of these laws is the conservation of energy, or the constancy of force, that is to say, the maintenance of an equal quantity of motion, actual or virtual. Such is the affirmation, as we have seen in our preceding studies, upon which modern physics are founded. Physiology is proving, more and more clearly, that the phenomena of living bodies are subject to the laws of physics. The human body is included in the *ensemble* of universal motion; its proper motions are never anything else than the transformation, in equal quantity, of forces which it receives from the ground, the atmosphere, and the sun; it can only give back what has been given to it. Centripetal motions pass from the senses to the brain, and centrifugal motions pass from the brain to the limbs; but all motions of the organism which is the theatre of these phenomena have their equivalents in the external physical motions which have brought about its formation, and contribute to its maintenance.

A mind unacquainted with scientific discoveries will say:—"I will, and my arm rises; I create a motion which would not exist without the act of my will."

But, for contemporary science, the motion of my arm can only represent a part of the force which I have received from nutrition, respiration, the action of the sun. I can no more create a motion than I could create an atom of matter. In a system of bodies in motion, everything is determined by the laws of mechanics; in order that any modification whatever should take place, there must be a force. Now, the intervention of a force supposed free would change the quantity of the motion. If the principle of the conservation of energy is admitted, it follows as a consequence that everything is determined in a necessary manner in the motions of the human body as in those of all other bodies. But mental phenomena always have for condition, whether of their existence or their manifestation, the motion of matter. Therefore, the distinction of physical and psychical phenomena may well subsist; but psychical phenomena are absolutely determined as well as their material conditions. Therefore, finally, the affirmation of liberty is an illusion, since the exercise of liberty would destroy the universal determinism of the phenomena. The conflict between physics and morals thus becomes manifest. In fact—and it is a subject upon which it would be superfluous to enter at length—the existence of liberty is the foundation of morals. If liberty does not exist, duty cannot exist, and no more can responsibility. Moral laws as we conceive them are proposed to man without being imposed upon him; they admit of a violation which we call evil; they are laws of liberty. A serious psychology will always have to allow a large share to the involuntary element

in the sum total of human determinations; but if there do not remain an element of liberty, how feeble soever, in the crucible of psychological analysis, the line of demarcation between physical and moral laws disappears, and the actions of men can no longer be legitimately qualified as good or bad in the common acceptation of the terms. The acts may be noted, but the agents are not responsible beings who may be judged; there are no longer morals but only manners, the study of which belongs to the chapters of natural history. The conflict is, therefore, very evident between morals of which liberty is the fundamental postulate, and the tendency of thought which reduces all physiological phenomena to physics, and subordinates psychical phenomena to physiological determinism.

In many minds at the present day the conflict ceases by the negation of liberty; but it is not everybody that abandons without a struggle the cause of an idea of this importance. The study of the problem cannot be put aside. It is not possible to say:—"There is a science of forces, there is a science of minds; each of these sciences has its own province, and the one has no right to deny the results of the other." If every mental phenomenon has the motion of matter for condition, and if all the motions of matter, by virtue of the principle of the conservation of energy, fall under the law of an absolute determinism, there is no place for liberty. Motion is the indissoluble link between the world of bodies and the world of spirits. These two propositions, "all motion is necessarily determined—there are free motions," affirm and deny, in speaking of

the same object, and taking the terms in the same sense; they cannot subsist together, because they are directly contradictory. This is what makes the real importance of the question of the relations of physics and morals. Observation establishes more and more the fact that every mental phenomenon has a material correspondent, that all passive modes of conscious being have a point of departure in the organism, and that all active modes of conscious being are at once translated into an organic fact. There is nothing in this which tends to the negation of the spiritual order, or which can occasion the least anxiety to men concerned for the moral interests of humanity. We may even observe that the principle of the conservation of energy offers a new and considerable support to the theory which goes to prove the difference between corporeal and psychical phenomena. The question is, in fact, to recognise the equivalence of the motions of the organism in its various modifications. No thoughtful physiologist will have the idea of introducing into his equations facts merely psychical as distinguished from their material condition. These facts, therefore, are of another nature from the physiological phenomena in which it is sought to recognise the transformation of motions in equal quantity. Spiritualist theories have nothing to fear from the progress of physiology, in respect to the distinction between physics and morals; but if the active modes of the consciousness are subjected to an absolute determinism, every element of liberty disappears, and the foundations of morals give way. What, in this state of the question, are the efforts attempted to save moral

order from the stifling embrace of a science which suppresses liberty?

NEGATION OF THE UNIVERSALITY OF THE PRINCIPLE OF THE CONSERVATION OF ENERGY.

The *Critique Philosophique* of the 21st August, 1873, received and registered in its pages the following communication:—"The *Critique Philosophique* is forward and earnest on all occasions in defending the cause of free will. But, at the same time, it has promised in its prospectus to treat of philosophical questions connected with the physical doctrine of the conservation of force. It is desired to know what its honourable editors think of the possibility of reconciling this doctrine with that of liberty, or how they contrive not to see, in the theory which brings all natural forces to constancy and to unity, an irresistible argument in favour of universal determinism."

M. Renouvier replied by denying the universality of the legitimate applications of the principle of the constancy of force. "We do not admit," said he, "that the sciences go wandering out of their proper province, and are changed unduly into metaphysics. This is what happens when to the principle of the constancy of force is attributed a universality for which there exists neither warrant nor solid induction. We formally deny this universality." After having presented considerations regarding the relation of causality which exists between the desires, the will, the various psychical phenomena and motion, the author adds:—"The con-

stancy of forces would find, like determinism, a limit and an exception in liberty, and perhaps not in liberty only, but again in the animal passions which, simply occasioned by external motions, would have the property of producing others afresh."

This way of thinking may be justified by solid arguments. The affirmation of the maintenance of an equal quantity of motion actual or virtual in the universe, is, certainly, neither an *à priori* principle, nor the immediate expression of observed facts. Who has been able to observe, for instance, the equivalent of the motion which constitutes the solar rays, outside and beyond their action upon our planet? The conservation of energy is a hypothesis in the way of confirmation. If we admit that it is valid for the entire physical universe, yet,—beyond? In the province of physiology, the demonstration of the principle is far from being solidly established. It is shown, indeed, that the greatest part of disposable energy in animated beings comes from the chemical actions of nutrition and respiration,—that is to say, that the energy is *pretty nearly* conserved; but it is impossible to prove that it is so absolutely. One may admit that forces emanating from the vital or spiritual element produce an infinitesimal result which remains absolutely inappreciable by the most delicate experiments, and of which the effect may still be very considerable, just as by pressing in a manner scarcely perceptible upon the trigger of a rifle one produces enormous consequences.

In moral phenomena we meet with facts directly

observable which are opposed to the hypothesis of universal determinism. The sentiment of responsibility and the idea of duty are facts as certain for the conscience as motion can be certain for sensible perception. And it is not only to moral phenomena properly so called that one may appeal here, but also to psychological observation the most elementary and certain. A reflex motion is very clearly distinguished from a voluntary motion. If I choose to bring my hand near to a burning substance, I shall distinguish, without the smallest difficulty, the reflex or instinctive motion which will tend to keep my hand from it, from the voluntary motion by which I may resist the instinctive motion. The transition which takes place, through the effect of habit, from voluntary motions to motions which become instinctive, is one of the most important observations of psychology. How could we speak of the transition from one state of motion to another, if it were not for the existence of two distinct states? Will it be said that we are never conscious of any but reflex motions, to which we attribute, *in certain cases*, a voluntary character, through the illusion of liberty? Why should the illusion affect us in certain cases and not in others? Suppose we grant that we may arrive in this relation at a physiological determination, which is to grant a great deal; there remains another question. Whence proceeds in our understanding the idea of liberty, which we must possess to be able to attribute it in an illusory manner to certain motions? If the idea of liberty does not proceed from the observation of the consciousness,

whence does it come?[1] It is not a complex idea of which we can find the origin in elements brought together at random. Will it be admitted that it is an idea without cause? But if there may exist ideas without causes, why should there not exist also motions without causes? Thus the basis of all science is overthrown. By what right can be denied, starting from a physical hypothesis, facts of observation, which, though they lie outside the domain of sensible experience, are not on that account less certain and easy to establish? If we grant that the principle of the conservation of energy applies without exception or reserve to the purely material world, by what right are we to extend it to cases in which matter is found in relation with mind? From the fact that absolute determinism reigns in the object of the studies of the astronomer, the physicist, and the chemist, we have no right to conclude that it excludes the reality of the facts with which psychology is occupied. Such reasoning is based upon a manifest *à priori*; it is the case of a science which wanders from its own domain. To affirm the absolute determinism of acts held for voluntary, is to deny an immediate *datum* of observation, in the name of an hypothesis which only systematic minds can consider as theory absolutely demonstrated.

We see that M. Renouvier's thesis may be defended

[1] M. Fouillée (see above the note page 220) thinks that the idea of free will is the result of a combination of notions, in which figures, as one of its elements, "the idea of a relative *independence*, which is an object of experience" (page 593). What is a *psychical* independence, relative or not, into which free will does not enter in any degree?

by at least a specious process of argument. I hold that this is very solid argument, but it is another thesis which I am purposing to maintain.

CONCILIATION OF THE CONSERVATION OF ENERGY AND LIBERTY.

By admitting the principle of the conservation of energy, and extending it to the human frame, to all conditions and all manifestations of the spiritual life, the cause of moral liberty is not compromised. The conflict between physics and morals is apparent only, because:

1. In relation to space, the direction of motions may be modified, their quantity remaining the same.

2. In relation to time, the actual manifestations of a constant amount of force may be produced at different moments, without change in the quantity of force.

If these two theses can be proved, the conflict between physics and morals disappears. In fact, morals do not require the existence of a power *creative* of force, but only the existence of an element of liberty in the *employment* of a given force. Let us first examine the first point.

If in thought we isolate a planet from its system considered as a whole, it is clear that it may move in its orbit in one direction or another, the quantity of its motion remaining equal; this is the undeniable consequence of the dynamic indifference of space. Similarly, when a locomotive is placed upon a horizontal railway, it may take one direction or another, the force of the

machine and the force employed by the engineer remaining the same. Therefore, the direction of the motion may vary, without variation of the quantity. I put forth this idea in the *Bibliothèque Universelle* of July, 1873, without noticing at the time that it might be an unconscious reminiscence from reading Descartes,[1] and without knowing that M. Carnot had published the same idea.[2] A correspondent of the *Critique Philosophique*[3] disputed my affirmation, basing his argument upon the identity of the notion of force and that of motion. This identity of force and of motion has been affirmed by several savants of the day. M. Beaunis, for instance, says that the first of the general laws of motion is that "every motion has a motion for its antecedent."[4] M. de Candolle asserts, on the faith of physicists, that "every motion has for cause an anterior motion." If this is admitted, if every force is a motion, the objection made to the thesis which I have maintained is irrefutable. When one conceives of the absolute commencement of a motion, it is very clear that, the quantity being the same, the direction may be different; but experimental science has never to take into consideration an absolute commencement. The human will intervenes in a determined system.

[1] "Descartes admitted that souls cannot give force to bodies, because there is always the same quantity of force in matter. Still he believed that the soul might change the direction of bodies."—Leibnitz, "Monadologie," § 80. See also the "Considérations sur le Principe de la Vie," by the author of pre-established harmony, towards the beginning.

[2] "Séances et Travaux de l'Académie des Sciences Morales et Politiques," tome cix. page 704. [3] 21 Août, 1873.

[4] "Nouveaux Éléments de Physiologie Humaine."

If it modifies the direction of a motion, it acts as a force; and if every force is a motion, it cannot intervene without modifying the quantity of universal motion. The question, therefore, is to know if we have the right to identify force and motion. Now, this identification is by no means justified; on the contrary, it is formally contradicted by a just interpretation of the phenomena. Here is the capital point of the discussion.

What is a force? "A cause of motion, or of modification of motion."[1] The progress of astronomy tends to confirm the fact that all the stars of the heavens are in motion. The idea has long been given up that the earth is the motionless centre of the universe; and now it is admitted that the sun himself changes his place relatively to the stars, together with his retinue of planets. At the same time, the science of physics leads us to consider bodies motionless in appearance as being the sphere of continual molecular motions; and that, in an absolutely calm atmosphere, heat and light are incessant undulations of an ethereal fluid. Bodies may be relatively at rest upon the surface of the terrestrial globe, just as objects may be relatively at rest upon the deck of a ship; but, so far as we can know, everything, in the whole domain of our experience, is in motion. The passage, therefore, from absolute rest to motion is never taking place. Hence it follows that, reserving the question of the first origin of universal motion, which could not be an anterior motion, we may remove from the definition of force the idea of a cause of motion in

[1] Delaunay, "Traité de Mécanique Rationnelle," § 84.

the sense of creation, and keep only this formula: "A force is a cause of modification of motion." Now, the question comes to this: is a motion modifiable otherwise than by another motion? No. In physics we are obliged to consider the *presence* of bodies, and not only the *motion* of bodies. Chemical affinity is not yet brought to a physical phenomenon. The same is the case with the law of gravitation. In the calculations of the astronomer, the presence of a star, independently of its motion, appears as a cause of modification of the motion of the other stars. No hypothesis reckoned as valid has yet succeeded in explaining attraction by an antecedent phenomenon of impulsion. "Astronomy," says M. Bertrand, "has revealed an invariable and precise rule which, while remaining inexplicable and incomprehensible, explains everything and makes everything to be understood."[1] When it is said, "Every motion has for cause an anterior motion," which allows it to be affirmed that, in the province of physics, every force is a motion, it is therefore forgotten that, in the theory of gravitation, the mere presence of a body intervenes as a cause at which thought is arrested. If we supposed that gravitation had been reduced to an impulsion, would it be allowable to say that every force is a motion? No. When a body in motion meets another body, its motion is found to be modified. There is therefore in this phenomenon the manifestation of a cause of modification of motion—that is to say, of a force. What is the

[1] "Discours à la Séance Publique de l'Académie des Sciences," 10 Mars, 1879.

subject of this force? The body which has been encountered, and which may be supposed to be relatively at rest, will have undergone a modification. I put aside this part of the phenomenon, and consider only the modification experienced by the body meeting the other. Bodies have no power to modify their own motion—such is the expression of the law of inertia; as regards themselves they are not forces, but they are forces with regard to other bodies in the modifications of motion of which they are the origin. As Euler has remarked, it is the resistance of matter which is "the real source of the changes which we observe in the motion of all bodies."[1] As a matter of fact all bodies are in motion; but it is not in that it moves that a body in a state of relative rest modifies the motion of other bodies; it is in that it resists. The third of the principles of dynamics is that "the effect produced by a force upon a material point is independent of the motion previously acquired by that point."[2]

It follows from this principle that when two bodies being, for instance, one and the other upon the deck of a ship have the same motion, the action exerted by the resistance of the one upon the particular motion impressed upon the other is the same as if their common motion were suppressed.

Matter, therefore, is force by its resistance, but it is not impulsive force. Neglect of this essential distinction may lead the mind into grave errors. This is what happens when, confounding the force of resistance with

[1] "Lettres à une Princesse d'Allemagne," partie ii. lettre 2.

[2] Delaunay, "Traité de Mécanique Rationnelle," § 89.

the force of impulsion, the identity is maintained of the two ideas of force and matter. Matter is determinable for us only by the resistance in virtue of which bodies occupy a portion of space. This resistance being a cause of modification of motion is a force. It certainly seems, therefore, at first sight, that the idea of matter and that of force are confused; but this is an illusion. The occupation of a part of space which is manifested by form is a *geometrical* conception distinct from the *dynamical* idea of the power by which the resistance of one body modifies the motion of another. The difference subsists in the case in which we conceive of the element of bodies, or the atom, as being only the centre whence a force radiates, in such a way that the *actual* occupation of a portion of space is relative, and may disappear by the effect of a sufficient pressure, so as to become simply *virtual*. There remains always, in fact, the centre of the force, that is to say, a power concentrated in a point, and the idea of the point which is the principle of all localisation, preserves, in opposition to every dynamical notion, the character of a geometrical conception.

It may be well to repeat that the force of resistance, which constitutes for us the idea of bodies, is not the principle of any impulsion. This force modifies motion, but on condition that the motion exists; for, of course, the existence of a thing must precede its modifications. It is, therefore, impossible to reduce to unity matter and force, the geometrical and dynamical element, without taking the term force in an equivocal sense, by which are identified in an improper manner the two

distinct notions of impulsion and resistance. To explain the phenomena which the physical universe offers to our observation, we must have matter, motion, and the laws of the modification of motion. M. de Candolle acknowledges this. After having said: "All motion has for cause a previous motion," he himself limits the absolute character of this affirmation by saying that the explanation of phenomena supposes "the double basis of motion and of obstacles."[1] The obstacles are the resistance which bodies in a state of relative rest oppose to the motions of other bodies. In physics, therefore, it is not only motion which is force, or cause of the modifications of motion, but also the presence of bodies. Now, the presence of a body may be conceived of as a force which changes the direction of motion without changing its quantity.[2] Let us suppose, in fact, a system of bodies in motion, and place in it, in our thoughts, a body considered as primitively motionless; the direction of the motions of the system will be changed without alteration of the quantity. Of course it is a purely theoretical conception which is in question here, since a body cannot be introduced without its introduction being a motion. But, supposing the spontaneous appearance of a body in a given system, that body would change the direction of the antecedent

[1] "Historie des Sciences et des Savants, depries deux siècles," page 464.

[2] M. Fouillée (see above the note page 220) does not admit the distinction between the presence of a body and its motion, because he considers the body as "a system of motion," or "an *ensemble* of motions" (page 601). His objection supposes, therefore, the identity of the idea of body and of the idea of motion. See on this subject page 25 of the present volume.

motions and not their quantity, and that is all that I wish to establish. To recapitulate : the explanation of physical phenomena supposes the form of resisting surfaces, an element of geometry which will never be replaced by the arithmetical computation of the quantity of motion. We will now pass on to biology.

Do the laws of physics, in the most general sense of that term, give account of vital phenomena? In the present state of researches—No. For a positive and prudent science all the manifestations of life suppose the concurrence of physical laws and of the laws proper to the organism. This is one of the affirmations upon which Claude Bernard has most insisted. To reduce life to the pure mechanism of matter, it would be necessary to prove that the seeds or germs are pure aggregates, and that the phenomena of the development and generation of the organisms are of the same order with the phenomena of cohesion and affinity. We do not possess the bases of a serious induction which allows us to raise this supposition to the height of a theory. Will it at some time be otherwise? This no one can say with certainty. We may remark that it is most generally philosophers and naturalists who think that life may be explained by the laws of physics. I believe that it would be difficult to mention a physicist of any importance who asserts that his science accounts to him for vital phenomena. This is not, however, the object of my study. It is enough for me to show that in the present state of our knowledge it is natural to admit that in living beings, and first in germs or seeds, there exists a special cause of disposition of physical

motions. This admitted as a possible hypothesis (I do not ask more), we arrive at the conception of a plastic force which changes the direction of motions without modifying their quantity. A field is sown. The grains of corn are some living, others dead. All the motions are alike, including that of the sower; and with the same action of the sun, the air, water, the results obtained will be different. One part of the grains will be decomposed; another part will produce plants, by giving a determinate direction to surrounding physical motions, which are exactly the same for the dead seeds and for those which have preserved vitality—the principle of life. This consideration enables us to understand the words of Claude Bernard, who, for biological explanations, has recourse to the idea "of a vital force which is *legislative* but not at all *executive*."[1] How are we to understand that there is something executed without an executive force? We understand, in social questions, the existence of a legislative power, coming to decisions which another power executes; but what is a legislative *force?* We do not understand; but what we understand very well, and what gives an entirely satisfactory sense to the words of Claude Bernard, is the thought that there exist in living beings *guiding* and not *creative* forces, which, in various ways, employ physical motions, the sum of which remains the same. We may grant therefore, for the interpretation of vital phenomena, the existence of forces which alter the direction of motion and not its quantity. This is pos-

[1] "Leçons sur les Phénomènes de la Vie Communs aux Animaux et aux Végétaux," page 51.

sible, and it will be probable so long as we have not ascertained in living germs a form of the aggregate and a motion which would be the intelligible antecedents of the development of plants and animals. Now, I repeat, any such discovery does not seem on the point of being made.

I have not here to put questions relative to the nature and the origin of germs. I only assert that the principle of the conservation of energy in the motions of matter is not opposed to the admission of forces, which, without being motions, would be causes of modification of motion, just as in physics the presence of a body is a cause of modification of motion without being a motion. This consideration applies to the human body as to any other organism. Plastic force, spontaneous as to physical elements, is besides determinate in its action, and realises a type which the external medium modifies by accidental influences, but of which the principle is found in the organism itself. I now approach in a direct manner the question which has led me to take up my pen.

Morals suppose and demand in man what is, to a certain degree, a self-determining power. In admitting that everything in the human frame is subjected to physiological determinism, so far as the executive part of the phenomena is concerned, it suffices, in order that the postulate of morals may remain intact, that there should exist an element of liberty in the *guiding* part of the phenomena. This just and profound remark we owe to Claude Bernard.[1]

[1] See in particular the "Rapport sur les Progrès et la Marche de l-

In the thirteenth book of the "Iliad," Paris says to Hector: "Valour will not fail us so long as strength remains to us; but it is impossible, do what we will, to combat beyond one's strength." No one can act beyond a certain limit; but one man may employ in fighting bravely the same amount of muscular motions of which another man will make use for flight. Though man disposes only of the quantity of force which he derives from food, air, and sun, it is enough that he disposes of it freely to constitute him an agent responsible for his actions. Therefore the bases of morals subsist, and the progress of a science which is continually showing in motion more and more the condition of spiritual phenomena in no way threatens injury to those bases. Now, what considerations are required in order to establish the possibility of an element of free will in maintaining the principle of the constancy of force? It suffices to admit for the will what it is impossible to refuse to the material molecule, and what probably cannot be refused to living germs,—namely, a power of direction which does not alter the sum of the motions. This consideration relates to space; a remark of the same nature applies to time.

The conservation of energy in all the motions of matter is not opposed to the admission of a power by which man may employ, at a given moment, and in a determined measure, the forces of which he disposes. To establish the thesis of the conservation of energy, it is necessary to admit that the principle of motion does

Physiologie Générale," page 233; and the "Leçons sur les Phénomènes de la Vie Communs aux Animaux et aux Végétaux," pages 61 and 62.

not exist only in the realisation of actual motions, but that it may exist also under a latent or virtual form. What remains in fixed quantity is not actual motion, nor actual live force, but it is the power capable of producing motion, or energy, which is at one time put in exercise, and at another time is merely potential.[1] The conservation of energy signifies the maintenance of an equal quantity of motion, actual or virtual; but the words must not create an illusion. Virtual motion, in the present state of our knowledge, is not a species of the genus motion, but *a possible cause of motion.* Wood in burning produces by its heat and flame a sum of motion equal to that of the motions which have produced its growth; the flame of the fire will only give back what the tree received from the soil, the air, and the sun; but how does virtual motion exist in the wood? Is there in the wood a molecular motion insensible to us which is transformed into the active power of the fire? A piece of artillery discharges its projectile; was there in the powder a molecular motion equivalent to that of the ball? No one assuredly has the right to affirm that it is so; because there is no proof of the affirmation. But let us grant that so it is; let us admit that potential energy is an actual molecular motion which is transformed, under given circumstances, into an appreciable external motion. The transformation may take place at different moments; the power of the external action may be expended or held in reserve, without change in its quantity. By reason of the dynamical indifference of space, the

[1] See the First Essay, at the article "Conservation of Energy."

direction of the motions may be changed, their quantity remaining the same. By reason of the dynamical indifference of time, a molecular motion may be transformed into an external appreciable motion, at one moment or another, without its quantity being changed. A taper contains a certain quantity of possible light. I put it out; its combustion is stopped, and its power to give light remains; the fact that it burns at one time or another is indifferent in regard to the quantity. In the same way, if we admit that all the external motions of the human organism are transformations of an internal molecular motion, the idea that the will may at one moment or another put into exercise the power of the organism is not in any respect contradicted by the theory of the conservation of physical forces.[1]

If it is so, there exists no real conflict between physics and morals. I do not create forces, but I dispose of those which I possess, and I dispose of them, at the moment I choose, for good or for evil. The fact that the quantity of possible motions is supposed fixed alters in nothing the responsibility of the agent who makes such or such an employment of the faculty of moving by which are manifested all the acts of the spiritual life.

The Question of Forces in General.

Motion is a universal fact. Science reduces to it all

[1] M. Renouvier has contributed some remarks on this subject well worthy of attention to the *Critique Philosophique*, of the 17th October, 1878.

physical phenomena, objectively considered, and all the conditions of spiritual phenomena. We recognise motion, and we admit that every motion has a cause. The principle of causality cannot receive an indefinite application. We rise necessarily to the conception of a primitive condition, which, without being explained, would be for all science the starting-point of all explanation; but if, when we take note of a motion in the series of phenomena presented to our observation, we admitted that it may have in itself its *raison d'être*—that it is because it is, without any antecedent, all research would be arrested. The cause of a motion receives the name of force. A force considered in itself, and not in its appreciable effect, is at first only an *x*, affirmed as to its existence, but undetermined as to its nature. To admit for each class of motions a distinct entity, and so to introduce into nature an Olympus of forces, is to realise abstractions, and to establish a sort of scientific mythology. To exclude the idea of force in order to retain only that of motion is a confusion. Motions have causes to determine, and the determination of these causes, or of the nature of the forces, is the principal effort of science. In physics, motion is modified by the presence or the motion of a body. In biology, physical laws not being able to account for the formation of the organisms, we must admit, at least provisionally, the existence of plastic forces, which entails no determination of their nature other than that of being able to realise the effects which they produce. In psychology, duty, responsibility, and all judgments which are derived from these primitive

data, suppose a force in some measure free, or a native power of action. The reduction of plastic forces to the laws of physics is not impossible in theory; it is only improbable in the present state of our knowledge. But, if the reality of moral order is admitted, it is impossible that psychical phenomena should be brought under the laws of an absolute determinism, since an element of liberty is the necessary postulate of all moral judgments. In order clearly to express my thoughts on this subject, I come back to the supposition of an observer acquainted with all the laws of physiology, and able to follow in every detail the action of the cerebral functions. This observer would be aware, in the first place, that all the motions accomplished by the human body have their equivalent in the action of diet, of the sun, and of the atmosphere, and are so the simple transformation of universal motion; so much for the quantity of motion, or for the element susceptible of an arithmetical notation. In the second place, as to the direction—that is to say, as to the element susceptible of a geometrical notation, the observer would take note of three classes of motions.

1. Purely reflex motions which, the organism given, are explained according to the laws of physics by causes immediately observable. Such are *mechanical* or transmitted motions, which form a chain, of which the first link is connected with a primitive state of matter.

2. Motions having their origin in a power proper to living germs. The development of organisms according to a determined type, and all transmitted hereditary

tendencies, enter into this class. They are *spontaneous* motions.

3. Motions the causes of which could not be placed either in one or the other of the two preceding classes. These are voluntary or *free* motions. The definition of liberty is here purely negative; but it is the only one to which physiological or external observation can reach. The direct affirmation of a productive power can only rest upon a psychological basis; it has no possible foundation in natural sciences; but as it is the postulate of the order of morals, it has the same value as the distinction between good and evil, vice and virtue.

These three classes of motions are distinct without being separated, since the life of organisms has for condition the laws of inorganic matter, and since, within the limits of our experience, the life of the spirit has for condition the physiological basis of the living body.

To recapitulate: the principle of the conservation of energy being admitted, there cannot be inferred from it the negation of human liberty. What does there remain to the free will? For the creation of motion, nothing; for the employment of possible motion, everything. The foundations of the spiritual order subsist, and have undergone no disturbance. The conflict of physics with morals is, therefore, apparent only, and I arrive at the conclusion to which Professor Boussinesq came in another way by mathematical considerations. We may admit the existence in man, without departing from the strictest data of science, of a principle directing motion; and, that admitted, " the physiologist may, without deviating from the severest spiritualism, extend

mechanical, physical, and chemical laws to all matter, including the molecules of the living brain."[1]

[1] "Conciliation du Véritable Déterminisme Mécanique avec l'Existence de la Vie et de la Liberté Morale." Par M. J. Boussinesq, Professeur à la Faculté des Sciences de Lille. Paris, 1878.

FIFTH ESSAY.

The Philosophical Consequences of Modern Physics.

PHILOSOPHY studies the general problems which originate, not from any particular class of facts, but from the total assemblage of the data of experience. For a philosophy constructed according to the rules of the scientific method, the results of all the sciences are a basis and a means of control, just as the facts immediately observed serve for basis and control to particular sciences. Hence it follows that discoveries made in any order of studies whatever, when they have the character of general truths, must exert an influence upon philosophy. This rule of method is lost sight of by speculative minds which have the pretension to construct science *à priori*, by means of the data of the reason alone. The attempt is brilliant, but it is chimerical. Of any system so constructed one may say, in the words of Corneille:

> "As of glass it has the brightness,
> So has it the fragile lightness."[1]

In reality, all solid philosophy, whether it knows it or not, undergoes the influence of the development of particular sciences. The theory of Copernicus, for

[1] "Polyeucte," Acte iv. scène 2.

instance, has powerfully acted on the general conceptions of the mind. It has given reality to the idea of immensity, the infinite character of space—an idea which exists virtually in the understanding; it has also modified in its applications the doctrine of final causes. A mind initiated in the discoveries of modern physiology will not willingly accept the definition of M. de Bonald, who made of man "an intelligence served by organs." The observations relative to the connection of corporeal and psychical phenomena determine the views with which one may approach the general question of the relations of mind with matter.

Does a particular science require a development considerable enough strongly to fix the attention? There may be manifested upon occasion of this fact two different directions of thought, according as it is subject to the influence of one or the other of two tendencies analogous in appearance, and profoundly different in reality—the systematic and the philosophic tendency. The philosophic spirit has two qualities—generality in its inquiries, and the research of a principle of unity. All philosophy worthy of the name is a *monism*, because it labours to discover unity in the multiplicity of phenomena; but it must not draw its conclusions until after a serious review of all the orders of facts. It has as an essential condition a basis of analysis sufficient to render valid an essay of synthesis. The systematic spirit is shown in essays of premature syntheses. It universalises a single order of facts, which more often than not leads to the conception of an arbitrary unity, narrow and consequently false.

The development of modern physics, and the justification of the theories of that science by the admirable advances in arts and manufactures, are one of the most striking intellectual characters of our times. The systematic spirit has seized upon this fact, and there has resulted from it a very sensible modification in the state of contemporary philosophy. In 1843, M. Franck affirmed, in the preface to the "Dictionnaire des Sciences Philosophiques," that the doctrine of sensation was exploded, and materialism vanquished in a way which might be regarded as definitive. The official leaders of French philosophy thought at that time that the judicious observations of the Scotch, the profound analyses of Kant, and the studies of Maine de Biran had destroyed the prestige of thc audacious syntheses which Condillac gave out for analyses in his doctrine of transformed sensation. Since that epoch all is changed. In a great number of publications of the present day the affirmation that all our ideas have their exclusive origin in sensation is reappearing as an axiom; and works which have a wide circulation are reproducing, without any material change, the materialism of the Baron d'Holbach. If we go back to the sources of this movement of thought, we find, as the principal cause, a system of physics transformed into philosophy; that is, a particular science raised into universal science by a synthesis to which a sufficient basis of analysis is wanting. This intellectual phenomenon is shown in an interesting way in a narrative by Mr. Tyndall. The matter in question is, in truth, only a souvenir of an excursion; but the author has repeated the same

thoughts in an address delivered to a scientific assembly.[1]

Mr. Tyndall was coming down from the summit of the Matterhorn. He remarked, during a short halt, that that mountain, when seen from above, seems "torn into strips by the frosts and the ages." This spectacle awoke the thought of the savant, who gives the following account of what then passed in his mind:—

"This state of ruin implies a period of youth when the Matterhorn was, in a manner, in the full vigour of its age. Naturally the mind goes back to the causes which gave it its birth and growth. And thought does not stop there, but wandering farther, beyond worlds which have disappeared, it goes on to those nebulas which philosophers consider, with just reason, as the immediate source of all material things. Would it really be possible that the blue sky which stretches above our heads were a remnant of those vapours? And the azure which becomes more vivid on the heights—would it be changed into profound darkness beyond the limits of the atmosphere? I strove to fix my thoughts on those universal vapours, containing in them the germ of all that exists; I strove to represent them to myself as the seat of the forces, the influence of which is exhibited in the solar system, the stellar system, and all that they contain. Did that shapeless mist, then, virtually contain the *sadness* with which I was contemplating the Matterhorn? Did my thought, in

[1] See the Third Essay, in the section upon the Negation of the Inertia of Matter.

going back as far as to it, only re-enter its first abode? And, if it is so, should we not do better to remould all our definitions of matter and force? For if life and force are but the unfolding of these, every definition which omits thought and life is not only incomplete, but defective."[1]

In this passage, the *nébuleuses* are considered first of all as the source of *every material thing*. A few lines farther on these vapours are the germ of *all that exists;* and that there may be no indecision as to the import of these terms, the author states distinctly that the question which he puts to himself includes the feeling of sadness which was prevailing in his soul, and the thoughts which had presented themselves to his mind. This abrupt passage from the consideration of physical elements to that of the totality of existences is met with in writings, the authors of which pause a long while at theories of natural history, scarcely cast a superficial and heedless glance upon spiritual facts, and end in materialism. Mr. Tyndall acknowledges that, to make feeling and thought proceed from nebulous matter, we must change our ideas of matter and force, and in the scientific discourse in which he developed the thoughts hatched[2] upon the sides of the Matterhorn, he declares that he discerns in matter "the power of all the forms and all the qualities of life." This is, as was said in our Third Essay, positively to deny the doctrine of inertia. To deny the doctrine of inertia is to overthrow the basis of the labours of Fresnel, Ampère,

[1] "Dans les Montagnes," par John Tyndall, traduction Lortet, pages 349 et 350.

[2] *Ecloses.*

and Faraday, as well as of those of Newton and Laplace. It seems, therefore, that, dazzled by the progress of physics, the English savant does not perceive that he is destroying the foundations of the science which he has himself cultivated with brilliant success. We have here the spectacle of a mind which takes its flight [1] under the impulse of the systematic spirit. The philosophic spirit does not allow of the abrupt passage from the idea of material things to the idea of all that exists; it does not allow conclusions to be drawn from the data of a single science for the solution of the universal problem. The philosophic spirit must preserve from all bewilderment, and put all things in their place, physics as well as the rest. To put physics in their proper place is not to give up the recognition of the relations which they hold with philosophy. The object in this work is to interpret, in a legitimate way, the data which this particular science furnishes to science in general.

The science of modern physics took its rise from the affirmation that material phenomena considered objectively are reduced to motions, and from the doctrine of the conservation of energy, or the maintenance in equal quantity of the motive power in the various transformations of motion. It seeks its means of explanation in the application of mathematical formulæ to the motions of matter. Finally, the more it advances in its researches, the more it succeeds in explaining, by a small number of laws, the indefinite multiplicity of phenomena. Its programme is far from being accom-

[1] *Une pensée qui prend son essor.*

plished. The road which leads to the end in view is long, and has in store, it may be, many surprises; still, the bases of the science appear sufficiently solidly laid for the study of their philosophical consequences to be legitimate. I shall first apply myself to the question of method, and then pass in review some important doctrines.

The Scientific Method.

At the epoch when the foundations of modern physics were laid, Galileo pointed out and practised the true scientific method. He observed; he made hypotheses; and he accounted his hypotheses valid only in the degree in which their consequences were found conformable to the facts. But, notwithstanding the example of this wise spirit, and notwithstanding the eloquent claims put forward by Bacon on behalf of the rights of experiment, these were ignored, and the *à priori* method impaired the work of Descartes and his successors. This predominance of the rationalist came, in part, from the fact that the two greatest masters of the science in the seventeenth century, Descartes and Leibnitz, were mathematical geniuses. They believed that the science of nature could be established by the deductive processes which they had brought into use in analytical geometry and the differential calculus. Then came the reaction in favour of empiricism which characterises the eighteenth century. Rationalism was afterwards revived in Germany, in the philosophy of nature, and reached its apogee in the works of Hegel, who thought to construct *à priori* the laws of physics

and the combinations of chemistry, at the same time with the history of humanity. The fate of these lofty constructions has supplied an illustration of the proverb that pride goes before destruction. A fresh reaction has been produced in favour of empiricism, and has reached its apogee in the positivism which forbids thought to take a step beyond the simple arrangement of facts. Positivism allows no value to the tendencies of the reason, which desires to explain facts, and not merely to arrange them. Reason has taken vengeance for these insults by the return of the systematic spirit exerting its influence under cover of the experimental method. There is a sort of irony in the audacious and premature syntheses in which many minds are now-a-days indulging, while professing the theories of empiricism.

After the violent oscillations which have just been described, and in which the theorists of method passed from absolute rationalism to pure empiricism, and from pure empiricism to absolute rationalism, the time is come to draw from the history of science the lessons which it contains. To know whereabouts we are in the question of method, it is necessary to distinguish the guiding principles of thought, which have a simply *formal* character, and *à priori* affirmations, which have *substantial* contents from which we may deduce elements of system.[1] Descartes confounded these two distinct elements, and it is easy to ascertain that the durable part of his work was the result of guiding principles, and that the greater part of his errors had their origin in

[1] See the Third Essay, at the beginning.

the employment of the *à priori* method. The confusion made by the principal founder of modern physics was made by his adversaries. In repudiating *à priori* constructions, the guiding principles of thought were repudiated. Hence it followed that truths at this day recovered were overlooked for a time, because they were unjustly enveloped in the just proscription of the errors of the Cartesian physics.[1] The history of modern physics proves that science took its rise from the rupture with the *à priori* method, from the observation of facts accepted as the basis of theories and the means of their control, and from hypotheses conceived under the influence of determinate principles which, without directly affording the knowledge of any law, have directed researches on the road in which veritable laws were to be discovered.[2] So is placed in full light the scientific method which intervenes between empiricism and rationalism. It preserves, out of empiricism, the idea that the observation of facts is the basis and means of control of every serious theory, but abandons the while the notion that observation is the unique source of science. It preserves of rationalism the logical apparatus, which is the condition of all knowledge, and the guiding principles of thought, but rejects the pretension of *à priori* construction. The road by which the human mind can attain to that portion of truth which is accessible to it is thus clearly pointed out. The history of physics is the most solid confirmation which can be met with of the true theory

[1] See the Second Essay.

[2] See the "Logique de l'Hypothèse," third part.

of method. Let us now go on to examine the consequences which may be deduced from the discoveries of this science for the solution of a certain number of questions which enter into the programme of philosophy.

Idea of Matter.

We do not yet possess, and perhaps never shall, a settled doctrine upon the constitution of matter. The theory of atomism,—that is, of the existence in determinate number of the first elements of bodies, has an experimental basis in the law of definite proportions and in that of multiple proportions. When bodies are brought together in any quantities whatever, those bodies always combine in determinate proportions; this is the law of definite proportions. When one body forms with another several combinations, the weight of the one varies with regard to the weight of the other according to simple numerical relations; this is the law of multiple proportions. These two affirmations experimentally demonstrated, are explained by the thought that bodies are formed of indivisible parts. Besides, every attempt at mathematical synthesis intended to account for phenomena supposes that the elements of matter are definite in number. We may, therefore, consider the atomic theory as expressing one of the postulates of modern physics. But, admitting that this theory is proved, what is the nature of the atom? Is it impenetrable, as is usually supposed? Is it only a centre of force, in such a way that several atoms may coincide in one and the same place. These

are questions not resolved. What remains certain is that indefinite divisibility, an undeniable character of the conception of space, cannot be applied to the element of bodies, when once that element is considered as a unity. The confusion set up by Descartes between the idea of space and the idea of matter was, as we have seen,[1] the origin of some of his errors.

Philosophical questions relating to the nature of atoms are, therefore, not resolved. One may say as much of problems relating to the first form of motion. Precisely to state the question in one of its details,—Is gravitation a primitive motion, or has it a physical antecedent, as Newton supposed, and as many others thought after him? This is what we do not know, in the present state of researches.[2]

The science of physics does not, therefore, yield to general science a proved theory relatively to the constitution of matter, and to the primitive motion with which matter is animated; but it supplies the solution of a question agitated in the schools of philosophy.

A distinction has been often drawn between two sorts of qualities, or properties of matter; the qualities called *primary*, which are represented objectively, and which are connected with form and motion, and the qualities called *secondary*, which are the causes of the different sensations designated by the names of sound,

[1] In the Second Essay, article upon "The Errors of Descartes."

[2] A recent attempt to determine the physical antecedents of gravitation has been made by M. Endore Pirmez, in his work upon the "Unité des Forces de Gravitation et d'Inertie," 1 vol. in 8vo. Bruxelles, 1881.

colour, smell, taste. The value of this distinction has been disputed. M. Saisset, for example, has written: "The line of demarcation variously traced by Descartes, Locke, Reid, and Dugald Stewart, between the first and second qualities of matter, is more or less arbitrary and irreconcilable with facts."[1] The distinction, of which M. Saisset does not admit the value, equally disappears for the philosophical school which, with Stuart Mill, defines matter as "a permanent possibility of sensations." This definition does away with all serious study of the phenomena of perception, leaving in view of the subjective fact of sensation only a possibility,—that is, a realised abstraction, which very unduly takes the place of the necessary conception of an objective reality.

The distinction between the first and second qualities of bodies, attacked by some philosophers, is unquestionably justified by the theories of the existing system of physics. In fact, according to these theories, the causes of our sensations, which are undetermined directly in the fact of perception, are determined scientifically, as divers motions, whether of ponderable matter, or of ethereal fluid. We explain the second qualities by means of the first. How, after that, can the difference be ignored between phenomena explained and those which serve for their explanation; the difference between motions of matter—objective phenomena which are the object of a representation, and subjective states which result from the relation of sentient beings to motions? Here, it seems, is a question agitated by

[1] "Dictionaire des Sciences Philosophiques," article "Matière."

philosophers which is found to be definitively resolved by the progress of physics.

It would be advantageous, we may say here, to replace the terms first and second qualities, by the terms *essential* and *accidental* qualities. Form and motion are conceptions without which the idea of body disappears; they are, therefore, essential; while sound and colour are accidental qualities, since they may disappear, as in fact they do for the deaf and blind, without the disappearance of the fundamental idea of body.

IDEA OF SPIRIT.

Nothing can be known without the spirit knowing itself in the fact of consciousness. What we have to examine here is the way in which the spirit manifests itself to itself in the knowledge of bodies, which is the object of physics.

The distinction between material and psychical phenomena founded modern physics, as we have seen in the preceding essays. This distinction is necessarily introduced, particularly in relation to heat, in all elementary treatises. The sensations of heat and cold have a relative character. They are variable according to the constitution of individuals, and, for the same individual, according to the state of his organism at a given moment. Therefore, in order to make a scientific study of heat, it was indispensable to find a phenomenon which should manifest the different degrees of it, and which should be independent of personal impressions. This phenomenon was found in the motions

caused by heat, which produce expansion in most bodies, and which are the principle common to all thermometers. To rid the study of heat of the personal impressions which it produces is to put aside the subject of sensations, by distinguishing it from the objective elements of which sensations are the product; it is, therefore, to recognise the distinct existence of the sentient being. In order to reduce all physical phenomena to motion, it was necessary to ascertain the relations of motions with phenomena of another order—with thought, in the most general sense of that term. Science was born of this distinction, and it confirms it. To say that in material phenomena there is nothing but form and motion is to proclaim the immateriality of thought.

There is being made at present, in certain regions of the philosophical world, a considerable effort to destroy the dualism of mind and body. It is affirmed that physical and psychical phenomena are but "the double aspect of one and the same fact," or "the objective and subjective face of one and the same event." It is said that "the difference of states of consciousness and states of the organism is reduced to a simple difference in the mode of apprehension." This is the thesis of some contemporary authors, that of Lewes, for instance.[1] Here is an attempt to reduce to unity the duality of psychical facts and their objective conditions. This attempt has a double origin—it comes from philosophy and physiology.

The dualism of mind and body was established by

[1] "Revue Philosophique," de Décembre, 1879, page 643.

Descartes in the prolegomena to his physics. Leibnitz, who is in so many respects Cartesian, differs with Descartes on this point of doctrine. He tells how, after having been for a moment led astray by the doctrine of the vacuum and of atoms, he had rejected this purely mechanical conception, and arrived at the notion that the simple elements of the universe are forces which he calls *monads*. He writes: "I found, therefore, that their nature consists in force, and that hence follows something analogous to feeling and appetite; and that so it was necessary to conceive of them in imitation of the notion which we have of souls."[1] To extend the ideas of feeling and of appetite to all the elements of the universe was to destroy the barrier established by Descartes between bodies and thought. Leibnitz, however, maintains stoutly the essential distinction between the human spirit and the organism. Having spoken of animals, he adds: "Reasonable souls follow far higher laws, and are exempt from all that could cause them to lose the quality of citizens of the society of spirits,—God having so well provided for this that all changes of matter could not make them lose the moral qualities of their personality."[2] It is evident, besides, that the doctrine of pre-established harmony supposes the essential and primitive diversity of spirits and bodies. The mind of Leibnitz is occupied in two different directions, one of which leads him to bring matter and spirit together, and the other to establish their difference. Are these two directions of his thought

[1] "Système Nouveau de la Nature et de la Communication des Substances," § 3.
[2] *Ibid.* § 8.

to be reconciled? This is a question for the historian of philosophy. The first, disengaged from the counterpoise of the second, has been strengthened by the progress of the natural sciences. The organic conditions of spiritual phenomena have been carefully studied and indisputably established. A moderate acquaintance with the actual state of investigations suffices to point out the error committed by Descartes when he affirmed that he knew himself as "a thing which thinks,"—abstraction made of all feeling of the existence of the body. The data of an exact psychology fully confirm, in this relation, the results of the labours of physiologists. Two currents, therefore—one of them proceeding from Leibnitzian metaphysics, the other from physiology—have united to produce in the mind of some contemporary savants the affirmation that the corporeal and spiritual elements which, observation manifests to us are only the double aspect of one and the same fact.

This thesis is hard to understand. Physiological motions and psychical facts seem irreducible, by the fact of the absolute diversity of the mode of their knowledge. Observation establishes that, within the limits of our experience, a determinate state of the body is the condition of the possible manifestations of the mind. When it is said that we establish the relations of two orders of phenomena distinct without being separated, and united without being confounded, that is intelligible; but what means the affirmation that the same fact has two aspects, or two forces? Do they affirm the substantial unity of the common support of different phenomena? This is a thesis of

speculative philosophy, and this thesis has a double defect. First of all, it is absolutely sterile: from a substantial unity undetermined and undeterminable, nothing can be deduced. In the second place, the thesis is destitute of all valid proof. To establish it, it must be affirmed that wherever there is motion there is some psychical element, sensation at least. Sensation is a subjective fact of which consciousness alone furnishes us with the idea. To admit the sensibility of animals is, for the superior animals at least, the result of a serious analogy. This analogy fails when we pass to the vegetable kingdom; and much more still when inorganic matter is in question. To attribute an element of sensibility to stones and metals is an *à priori* affirmation, deduced from certain philosophical conceptions, and which observation does not justify in any degree. Besides, the partisans of the doctrine which I am examining do not announce the intention of formulating a thesis of speculative philosophy; they do not speak of a substantial unity, understood in a metaphysical sense, but they speak of a fact. Since the question is one of fact, it is natural to ask by what experiment it is ascertained. Is it the subjective fact, the datum of consciousness, which has an objective face? What is the objective face of a subjective phenomenon? If we speak of an objective condition—that is intelligible; but an objective face of a subjective fact is not intelligible. The very terms employed show the necessity of conceiving of an object which is placed in face of a subject. Is it the objective fact, motion, which has a subjective face? So it is that the

partisans of the doctrine appear to understand it. According to Lewes, "it is necessary frankly to adopt the biological point of view—that is, to regard mental as vital functions."[1]

The unique fact which has two aspects is, therefore, the physiological fact. This affirmation is very clear in itself; but what is not at all clear is the way to conceive of the subjective aspect of a motion. The word which one is forced to employ implies the necessary conception of a subject distinct from the object. Let us assume that this kind of talk is worthless:—one single fact has two faces, or presents itself under two aspects. An aspect supposes a spectator. "Every event, every sensation has a double aspect, objective and subjective, according to the mode of apprehension."[2] Very well; but who apprehends? Is it motion which is apprehended as sensation? Is it sensation which is apprehended as motion? No serious thinker would dare to maintain these paradoxes. Two classes of distinct phenomena are apprehended by the consciousness which perceives directly psychical facts, and, by their medium, their objective conditions. The presence of the subject which perceives its own modes and external realities is implicitly affirmed by the theory of the "two aspects." This theory sets in full light, by the very terms in which it is obliged to express itself, the duality of the spirit and body; it sets it in full light, and forces upon science its acceptance.

Research for a principle of unity is the tendency of

[1] *Revue Philosophique*, Décembre, 1879, page 643.
[2] *Ibid.* page 644.

the reason—a tendency of which philosophy is the most complete expression. We have here an example of one of the cases which are so frequent, in which this tendency leads the mind astray. The desire of unity cannot find satisfaction in the consideration of one of the elements of a duality directly irreducible—matter and spirit. The distinction which founded modern physics subsists; mind manifests itself in the knowledge of matter as a subject irreducible to its object. M. Du Bois-Reymond, addressing the German naturalists assembled at Leipzig, presented the following considerations upon this subject. After pointing out the mystery which the nature of matter and force offers to the mind, he continues:—

"At a certain epoch of the development of life upon the globe,—an epoch of which we do not know the date, which, however, in no way concerns us here, there arises something new and unheard of till then, something as incomprehensible as the essence of matter and force. The thread of our intelligence of nature, which goes back to infinite negative time, breaks, and we find ourselves in front of an impassable abyss; in a word, we touch the other limit of our understanding.

"This new incomprehensible phenomenon is thought. I am now going to prove, if I am not mistaken, in a peremptory manner, that not only in the present state of our knowledge thought cannot be explained by the aid of its material conditions, a fact about which there will be only one opinion, but also, that in the very nature of things it never will be so explained. The

contrary opinion,—namely, that there is no reason to give up all hope of explaining thought by the aid of its material conditions, and that this problem will one day be able to be explained by the human mind, thanks to the intellectual conquests which it will have made in the course of the ages; this opinion is the second error which I have set myself to combat in this discourse. If, in what I have just said, and shall say, I use the word *thought*,[1] it must not, therefore, be supposed that I have in view only the superior degrees of our intellectual activity. On the contrary, by *thought* I understand, as did Descartes, intellectual activity in all its modifications, and my proposition embraces all, even the simplest, and, so to speak, the lowest in the scale. To have an example of an intellectual phenomenon inexplicable by the aid of its material conditions, it is not at all necessary to think of James Watt imagining his parallelogram, or Shakspeare, Raphael, and Mozart creating their sublimest masterpieces. Just as the most energetic and most complicated muscular action of a man or an animal is not more inexplicable, after all, than a simple contraction of a single muscular fibre; just as a single secretory cell conceals in its interior the entire mystery of secretion, so the very highest intellectual activity is not more difficult to explain in principle by the aid of its material conditions than that activity in its most rudimentary form,—that is to say, sensation. When at the beginning of animal life upon the earth the simplest being experienced for the first time a feeling of comfort or discomfort, the impassable

[1] *Pensée.*

abyss of which I have just spoken was opened, and the world became thenceforward doubly incomprehensible."[1]

So, in the opinion of the Berlin professor, science has a double starting-point—matter in motion, and psychical phenomena. These starting-points are absolutely distinct, and they remain incomprehensible like all primitive data.

Mind, then, manifests itself in the knowledge of matter, which is the object of physics, as a subject irreducible to its object; and not only does it manifest itself in a general way, but it manifests itself in its different functions, as we are going to show.

What is the essential idea of matter? Its resistance in space. In the idea of resistance analysis discovers two elements—effort and obstacle. The conscious exercise of motive power is the origin of our knowledge of matter. Now, in effort mind manifests itself as will. To say that we know matter as resistance is to say that the exercise of the will is the condition of the idea of body. The worth of this analysis is disputed in the doctrines of English empiricism,—doctrines of which I borrow the summary from M. Ribot's work.[2]

The fundamental thesis of this school is that of Condillac: "The only primitive and irreducible psychological fact is sensation." Then comes another thesis: "The fundamental, irreducible experience, which gives the notion of exteriority, is resistance." How can these

[1] *Revue Scientifique*, du 10 Octobre, 1874, page 341.

[2] "La Psychologie Anglaise Contemporaine," par Th. Ribot, 2me édition. Paris: Germer-Baillère, 1875. See especially pages 423-425.

two theses be reconciled? By affirming that there exist "muscular sensations which inform us of the nature, and of the degree of effort, of our muscles." M. Ribot observes with reason that these sensations "form a genus apart," so much are they distinguished from others. And why so? If a diseased muscle causes a pain, it is a sensation of the same sort with all those which result from the state of the organs. If my muscles are moved by a purely physiological antecedent, I shall be conscious of a motion, the origin of which I shall not attribute to myself, but which may even take place against my will, as is the case in a conscious convulsive state. Muscular sensation is distinguished from all other sensations when it results from a voluntary act. The case then is different; there is a genus apart; but it is not a genus of sensation, or at least there intervenes in the phenomenon an element irreducible to pure modes of sensibility—effort. What is the subject of the effort? To say that our muscles make an effort, and that sensation informs us of the effort of our muscles, is to confound two ideas, the origin of which is absolutely different. We may have consciousness, through the medium of sensation, of the *labour* of our muscles, whether that labour be the result of a purely physiological antecedent, or of an act of will. But it is in this second case only that there is *effort*. Labour is an objective notion which applies legitimately to the muscles; but it is not the same with the subjective notion of effort. It is the subject, the *I*, which is conscious of its effort to which the muscles give way in resisting it. This resistance is

accompanied by a sensation; but, in the active modes of existence, the consciousness of effort is primitive, sensation is subsequent, while in the passive modes, it is sensation which is primitive, and effort is subsequent, when there is reaction. The will, therefore, is really the starting-point of the phenomenon which gives us "the notion of exteriority." Without the exercise of the will, we should not have the idea, either of our own or of foreign bodies.

The motive power reveals to the mind the essential qualities of matter; whence proceeds the knowledge of the second or accidental qualities? Physics reply: Physical motions determine in living bodies physiological motions to which sensations answer. Without the existence of beings capable of sensation, there would no longer be light, heat, smell, taste, but only motions which are the objective conditions of those sensations. Let us here note in passing the error of writers who speak of a primitive state of the universe purely mechanical, which, in the course of ages, would have produced, by a natural development, the properties called physical. A development cannot produce anything but what is virtually contained in its point of departure. Now, a state purely mechanical contains virtually nothing else than transformations of motions, and not, in any degree, the elements of phenomena of another order, such as sensation. Ages and thousands of ages in this way effect nothing. Without the existence of sentient beings, the properties of bodies called physical, in opposition to pure mechanism, could not make their appearance; this is the positive

teaching of modern science. In the knowledge, therefore, of the second or accidental qualities of matter, mind shows itself as endued with sensibility.

Man perceives and feels; the savant would give account of the object of his perceptions and the cause of his sensations. The physicist seeks to explain phenomena by discovering their laws. Laws are conceptions of the understanding. One easily comes to understand that, without the presence of sentient beings, phenomena which suppose an element of sensation could not exist. It requires a little more effort to understand that if there existed no intelligences there would be no laws; and yet so it is. Suppose that the material universe alone existed, would not the stars all the same realise the law of gravitation? Whether the law be conceived or not, would not things be so? So it seems; but when one reflects seriously, one comes to understand that the term *so* supposes the relation of facts to a mind which conceives them. If all intelligence actual or virtual, real or possible, be taken away, things will be, but they will not be *so;* it will not be possible to say that they are conformable to an order which no mind could formulate. The idea of law will disappear, as the ideas of light and heat disappear with the existence of beings capable of experiencing impressions. This affirmation is valid, but it is hard to understand, because it is required to think of a state of things in which thought should not exist.

The science of matter is not confined to establishing facts, it aspires to discover laws. Laws can only exist

in an intelligence which conceives them, and not in things considered in themselves, which are only the material conditions of possible conceptions. Therefore, in the science of matter, mind is manifested as intelligence. This is true of every science, whatever the object of it; but the science of physics sets this truth in a specially clear light. We have seen, in the First Essay, that one of the characters of modern science, which sums up more or less all the rest, is the mathematical explanation of phenomena. The mathematics suppose, not only intelligence in general, which is the case with all sciences, but the special intellectual data which belong properly to the mind, and form a part of its dowry, in what Bacon calls "a chaste and legitimate hymen of thought with facts." The employment of mathematics sets in a strong light the *à priori* element of the reason; the efforts made to reduce to a purely experimental origin the science of numbers and of figures remain powerless. The notions which are at the base of arithmetic and geometry are produced upon the occasion of experience. Without motion, we should not have the idea of space and forms; without objects perceived we should not have the idea of number. The conceptions of the reason are not realised except upon condition of the practical exercise of our faculties; without that they would remain in an eternal virtuality; but the condition which allows of their manifestation does not produce them. A germ is developed only upon condition of a certain degree of moisture and heat; but it is not heat and moisture which can account for the plastic development of which an

organism is the result. In the same way the ideas which are at the base of the mathematics are only developed upon condition of experience, but their contents are not experimental. Stuart Mill, wishing to interpretate geometrical conceptions in the way of empiricism, writes: "Our idea of a point is simply the idea of the *visible minimum*, the smallest portion of surface that we can see."[1] The point of geometricians is the principle, not extended, of all localisation in space; it is, so to speak, a sphere of which the radius is zero. To make of it a portion of surface, how small soever, is to misconceive the essential nature of the fundamental conceptions of mathematics. A philosophy which leads the mind to such extremities pronounces its own condemnation.

Though we should grant the experimental origin of the materials of arithmetic and geometry, it would still remain manifest that propositions and theorems are established solely by the laws of thought without recourse to experiment. It is therefore allowable to affirm that the employment, ever more extensive, of the mathematics in the explanation of physical phenomena is ever bringing more and more to light the part which the understanding plays in our knowledge.

To recapitulate: there is no knowledge of the essential qualities of matter without the exercise of the will; there is no knowledge of the second or accidental qualities of matter without the presence of sensibility; there is no science of matter without intelligence. It suffices, therefore, to observe the conditions of the science of

[1] "Système de Logique," livre ii. chap. v. § 1.

bodies to obtain the notion of mind in its three functions—to act, to feel, to think.

Scepticism.

The science of physics establishes the distinction between facts and thought; it manifests also their harmony, which alone renders the universe intelligible.

In the order of physics, facts are motions perceived directly by the functions of touch and sight, and perceived mediately, as causes of sensations, by the impressions which the motions produce upon us. Thought, which manifests itself in all sciences by its logical elements, manifests itself specially in physics by its mathematical elements. Facts and thought form two orders distinct and irreducible. If facts are well observed, if the veritable laws of phenomena are discovered, and if, lastly, the calculations worked out are rightly made, there is agreement between the facts and thought. The motions of the stars in the heavens, the motions of molecules in bodies, the undulations of the ether, are found conformable to the calculations of the savant.

It follows from this consideration that mathematical physics contain the refutation of scepticism, or at least of general and complete scepticism. What is, in fact, the principal source of scepticism? It is this: The existence of thought is absolutely certain; one can only deny thought by exercising it—that is, by falling into a manifest contradiction. This is the irrefutable part of Descartes' *Cogito ergo sum.* One may deny the legitimacy of the passage from the fact of thought to the

affirmation of the substantial and durable reality expressed by *I am;* but it is impossible to dispute the certainty of thought, and of its inherence in a subject, at least phenomenal, expressed by the personal pronoun. *I think:* this is an absolute certainty for him who pronounces these words; but it is the only knowledge the character of which is immediate. Condillac begins his "Essai sur l'Origine des Connaissances Humaines" by saying: "Whether we mount, to speak metaphorically, to the skies, or whether we descend into the deeps, we do not depart from ourselves; and it is never anything but our own thought that we perceive." How shall we prove the agreement of thought with an objective reality? It would for that be necessary to be separate from thought, and to compare it with something else than itself; but this is impossible. Therefore we think; but we are unable to establish the relation of our thought with a reality; such is the fundamental basis of universal scepticism.

This argumentation is specious, but it does not hold against attentive examination. First of all, let us consider mathematics. I make a mistake, suppose, in an arithmetical calculation, or in a demonstration of geometry; I correct my error, or some one else corrects me by pointing out the mistake which I acknowledge. How can this be? Because the inner or subjective knowledge by which mind manifests itself not only reveals to me my individual thought, but also another thought which I am compelled to entertain—at one time by its immediate evidence, at another by means of a demonstration. It is necessary, therefore, to distin-

guish, in the total act of the consciousness, between a specially psychological observation which makes known to me the modes of my individual thought, and an observation which may be called *rational,* which sets before me a rule from which my individual thought may deviate, and to which it returns when corrected of its error. This rule, to which my mind must conform, is in me, without being myself, or mine. It is not *my* reason, in a personal sense; it is reason, in a general sense, common to all intelligences like to mine, and in which I participate. Mathematical truth results from the agreement of individual thought with its law. When I possess this truth, I possess a thought which is not mine only, or that of any particular individual, but that of the human mind. Here we are outside a subjective idealism which would constitute complete scepticism; but a new question arises—How shall we establish the relation of human thought with a reality foreign to that thought itself? Having escaped from a personal idealism, shall we remain in a collective idealism, which would not keep us clear of scepticism? No.

The perceptions which reveal to us the existence of bodies take place only through the medium of the consciousness; but these perceptions compel our attention by a sensible evidence, just as rational truth demands our acceptance of it by an intellectual evidence. The simple imagination which represents to me material objects is distinguished from perception, as my individual thought is distinguished from reason. A man who should have totally lost the faculty of

conceiving mathematical truths, and who should be incapable of seeing a mistake in a very elementary calculation, would be affected with imbecility or mental alienation. In like manner, (reserve being made for the case of sleep) an individual unable to distinguish a purely subjective appearance from a real perception is affected with the unhealthy condition described as hallucination.

It is impossible to deny the essential difference which exists between the abstract thought manifested in calculation, and the perception of sensible realities. Now, the object of human perceptions is a series of phenomena which are regulated conformably to the laws of mathematics. This conformity of phenomena to the laws of thought, or of the laws of thought to phenomena, is the condition of a possible science, and the existence of real science proves that this conformity exists. Mathematical physics do not, and cannot, make any progress, without manifesting, ever more clearly, the agreement of experimental realities with the reason.

Modern physics, then, have as a legitimate consequence the destruction of universal scepticism as it was manifested at the epoch of the thinkers of Greece. We read in the legendary history of Pyrrho that that famous sceptic, doubting of the evidence of his senses as of everything else, would not turn aside on approaching a precipice or meeting a chariot, so that his disciples had to be constantly about him to preserve his life. Now-a-days men do not doubt the evidence of their senses properly interpreted, and it is admitted

without dispute that we may obtain a true knowledge of natural phenomena. We believe in science, and scientific industry justifies the confidence accorded to the theories which serve as its foundation. General doubt is beating a retreat; it can no longer show itself except as a play of intelligence to which even those who indulge in it can no longer ascribe any serious value. There is here a considerable fact in the history of human thought, and one too little remarked—the scepticism of the ancients has given place to the positivism of the moderns. Doubt bearing upon religious and philosophical questions has not disappeared; it maintains its ground, one may even say that it is increasing. But why is it increasing? It is a comparative doubt, which comes from opposing the certainty of science to the uncertainty of all that goes beyond experience. We may say that it is the light which has been thrown upon one part of human knowledge which casts a shade upon another part of that knowledge; or, to make another comparison, it is because thought has found firm ground in the study of the phenomena of matter that it refuses to venture beyond that ground.

The progress of physics is the principal cause of this position of men's minds; but this situation is unstable. Positivism, if we consult its official programmes, does not allow of any philosophical affirmation—idealism, or materialism, or theism, or atheism; we can do nothing but arrange the data of experience; beyond this we know nothing. Under cover of this official doubt comes in negation. To the formula: "We know

nothing beyond experience," succeeds this other formula: "Beyond objects of experience, and sensible experience, there is nothing." Still, the tendencies of the reason subsist, and reason carries in it transcendental notions of the infinite, the absolute, the necessary. It often happens, therefore, that we see these transcendental notions applied to the object of sensible experience. It is affirmed that matter is eternal, and that the laws of nature are necessary: here is materialism. That positivism, which is officially doubt about everything which exceeds sensible experience, is frequently transformed into materialism, is what it would be easy to establish, by quoting facts and written statements. Does the development of physics, which has played a considerable part in the production of positivism, legitimately produce such consequences? There are good reasons to think otherwise.

MATERIALISM.

The systematic spirit, by connecting itself in an exclusive way with the data of physics, engenders materialism. By applying to the results of this science the philosophical spirit, we arrive at different conclusions. The science of modern physics, which destroys the scepticism of the ancients, destroys equally their materialism. What, for Democritus and Epicurus, were the data which were to furnish the explanation of the universe? Atoms, aggregated and disaggregated in an infinite number of fortuitous combinations, had produced at last the universe as it is. Such is the ancient

materialism. Modern materialism has other characters. It explains the world by a primitive disposition of matter, by motion, and the laws of the communication of motion. It is by a development wrought according to determined laws, or, to employ the term most used now-a-days, it is by an *evolution*, that the universe, starting from a primitive condition, has reached its present organisation. Now, the idea of an evolution—a development, subject to laws which science is seeking to discover, differs profoundly from the ancient notion of atoms moving at random, and forming a series of fortuitous aggregations. It is the progress of physics which has wrought this capital change in the idea of science. Materialism may seem to be strengthened by this modification, assuming thus a seriously scientific character which was wanting to it in ancient times, but in reality it proves to be destroyed. In fact, the fundamental ideas of science are these:—

Universal motion is regulated in a manner conformable to the laws of thought.

The universal force, or initial motive power, is constant.

The indefinite multiplicity of phenomena is produced by the combined action of a small number of causes.

Such are the undisputed results of the theory which interprets the experimental data. If, therefore, we desire to rise to a doctrine relative to the origin of the universe—that is to say, if we wish to attempt a philosophy—we have for starting-point the data following:—

The first mover exercises his power in a way of intelligence.

His action is constant, and has for effect to obtain innumerable results by a limited number of means.

These are assuredly the marks of what we call wisdom. Thus we find ourselves very far removed from materialism. The science of physics, when it confines itself to the direct study of its object, does not rise to conclusions of this nature; but the premises of these conclusions are distinctly disengaged from the most general results of the science of matter, and make part of the contribution offered by that science to the study of the universal problem which is the proper object of philosophy.

THE DOCTRINE OF CREATION.

It was said in our First Essay that the highest ambition of physics is to arrive at the determination of the primitive nebulous matter. We might then deduce all material phenomena from the disposition of the elements, from an initial motion, and from the laws of the communication of motion. This supposed starting-point is held for primitive. The actual organisation of the universe would be explained by means of these data, beyond which thought would not go back. The idea of a development, an evolution, was foreign to the seventeenth and even to the eighteenth century. The prevailing idea at that epoch was that the universe had been organised from the beginning as it now is. It is to Descartes, as we have seen, that is traced, in

modern times, the idea of inquiring how the universe could have been progressively organised.

The theory of evolution is the expression of an historical fact; it is the statement of a law expressing the mode of succession of phenomena. The dynamical indifference of time is opposed to the considering evolution as the expression of a productive power—a cause. One meets, however, in certain writings of the day, with the idea that time is a *factor*,[1] and the doctrine of evolution is opposed to the doctrine of creation. The matter in question is a thesis of philosophy which seeks its support in the progress of physics. Is the support solid? Is the filiation of ideas legitimate?

The nebular hypothesis being admitted, what is the origin of the nebulous matter, of the disposition of its elements, of the initial motion, and of the laws of the communication of motion? These questions are foreign to the science of physics which, in its quality of a particular science, is concerned only with establishing facts and accounting for their mutual connection. Whether the point of departure be an existence by itself, the nature of things, or the product of a creative will, is of no sort of importance to the labour of physicists. It would seem, therefore, at first sight, that the results of this labour can bring no light to philosophy for the solution of its fundamental problem. An attentive study of the subject leads to another conclusion.

[1] "Time seems to me more and more the universal factor."—ERNEST RENAN, *in the Revue des Deux Mondes of the 15th October*, 1863, page 762.

The theory of evolution had its origin in discoveries of geology first of all, then in the doctrine of transformism in natural history. The idea that all actual organisms are come, in the way of regular generation, from organisms primitively similar is opposed to the idea of successive creations. Let us put aside the idea of creation in order to keep clear of all data foreign to the domain of experience. The question agitated among naturalists is this: Have there appeared, at a certain time, new vegetable or animal species formed directly from the elements of the soil and atmosphere? or, do the fauna and flora proceed from similar organisms diversified under the action of physical causes? This is a question of biology which it may be that experimental inductions will be able with more or less certainty to resolve, and which does not come within the scope of my present study. Let us keep on the ground of physics.

If we think that the universe is fixed in its motions, that the solar system and the other analogous systems have been always organised as they now are, we understand that the universe may be eternal, or at least we think we understand it. This thought existed in ancient India. "The sons of Çakya held strongly this maxim, that the revolution of the world had no beginning."[1] In the seventeenth and eighteenth centuries, it was generally thought, if not that the world had had no beginning, at least that it began to be such as it is. Voltaire refused to admit "the

[1] Burnouf, "Introduction à l'Histoire du Buddhisme Indien," page 573.

changes which some believe they see in the course of ages," to which Buffon was beginning to draw the attention of savants. He wrote: "Nothing which vegetates or is animated has changed; all species have remained invariably the same: it would be very strange that the grain of millet should preserve its nature eternally and that the globe itself should change."[1] In these days, there is no dispute as regards either the diversity of vegetable and animal species which have successively covered the surface of the globe, or the changes which the globe itself has undergone; and hence follow important consequences.

Every development supposes a commencement. In fact, a development is produced in a given time, reckoning from a point of departure. Matter has produced the existing organisation of the physical universe by successive modifications of its motions. If matter and motion were eternal, the moment that one would take as a point of departure would have behind it an indefinite time. Therefore, the universe must have arrived at its actual state at some moment or other of duration, since at some moment or other of duration it would have had the time supposed necessary for arriving at the present state. As soon as we bring in the thought of eternity, all point of departure disappears. In his lectures delivered at Turin, in 1832, Cauchy proposed to his audience a mathematical demonstration of this thesis: "Matter is not eternal." What one can certainly demonstrate, is that

[1] "Les Sciences au XVIII. Siècle," par Emile Saigey, livre i. chap. viii. et ix.

a motion which produces a development cannot be eternal. There must necessarily be for science a point of departure. What idea can one entertain of this point of departure? Will it be a state by itself, without antecedent? In going back in evolution we arrive at the nebulous matter; shall we suppose the nebulous matter eternal? Motion will have been manifested in it at a given moment. Why? We can find no cause in the *moment*, that is to say in the category of time. It would be necessary, therefore, to admit a power in the matter itself, which would be contrary to the doctrine of inertia, or else to admit the manifestation of motion without cause, which would be the negation of the bases of all science.

If the nebulous matter is not supposed eternal, whence comes it? Is it non-existence which will have become transformed into being? To admit this would be to admit a contradiction properly so called, since non-existence is not less the negation of virtual than of actual being. To admit a contradiction properly so called, though Hegel could speak of it, is to ruin thought in its foundations. If we refer the origin of the universe to the manifestation of a power existing of itself, conceived of as a free and creative power, the nature of this power and the mode of its action offer, no doubt, great difficulties to the mind, but we shall have at least the means of understanding, for matter and its motion, the existence of a point of departure which will give a basis for evolution. If we will enter upon the question, we can only choose between a contradiction properly so called, and the difficulties attaching to the

doctrine of creation. It is allowable, assuredly, not to come to a decision; we may except against the competence of the human mind in such matters, and no one is obliged to take up with philosophy. Only we must avoid implicitly settling questions by saying that we do not broach them. If we will decide, the choice could not be doubtful between a difficult conception and a contradiction. Auguste De la Rive entered upon this subject when concluding one of his lectures on physics at the Athénée of Geneva. He had just been stating that all development excludes the idea of eternity, and supposes a commencement; he added: "It matters little that that commencement may have taken place thousands or millions of ages ago: that is not eternity. Now, motion could not have birth spontaneously; an external cause was necessary to engender it—a cause having *will and intelligence*. Whence I necessarily infer the existence of a supreme and personal Being."[1]

I will not affirm that the conclusions of this physicist are those of physics. We cannot directly infer, from the results of the science of matter, the full affirmation of theism; but the following reasoning appears to me to be sound: The motion which produced the existing universe cannot be eternal; it therefore demands an antecedent, by virtue of the principle of causality. This antecedent must be conceived of as foreign to the motion, by the very position of the question. It must be, therefore, that, to employ the terms of Aristotle, the first mover be itself immovable. This condition is

[1] *Chronique Genevoise*, du 11 Janvier, 1868.

satisfied by the idea of an Eternal and Creative Spirit.

The doctrine of evolution and the doctrine of creation cannot replace one another, because they are theories of two different orders, and which do not concern the same object. The first expresses a law of succession of phenomena, the second affirms a cause. To admit that the law replaces the cause is an error of metaphysics. It is an error which is committed by those who speak of substituting the idea of evolution for that of creation, as if time could be a power. In a particular science, abstraction is made of first causes, and the attention is confined to the succession of facts according to determinate laws. If we enter upon the supreme question of philosophy, it must be acknowledged, not only that the theory of evolution cannot replace the doctrine of creation, but that, far from contradicting it, it affords to it a sufficiently firm support. In fact, it places the mind in presence of a point of departure which demands a cause other than an antecedent which would itself be subject to evolution.

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